Structural change, wage inequality and technology foresight policy

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“surrealism comes from the reality of Latin America”
Gabriel García Márquez

Statement of contributions

This thesis is based on both co-authored and single-authored work. *Chapter 2* and *Chapter 4* are co-authored with Uwe Cantner and Carlo Pietrobelli respectively. *Chapter 3* is entirely based on my own contribution.

In particular for *Chapter 2*, I contributed to the idea of the topic, data collection, literature review, and writing of the results. My coauthor, Uwe Cantner, substantially supported the paper in the data analysis, by providing an original identification/interpretation of the productivity decomposition, along with its role as supervisor. The total amount of work has been spread by 60% for me and by 40% for my co-author.

In *Chapter 4*, I was in charge of the writing of the paper, including both the literature review and the case studies. My coauthor, Carlo Pietrobelli, elaborated original ideas for the definition of the case studies. Additionally, he systematically corrected and reviewed all the writing of the paper, which was ultimately carried out together and from long distance. The spread of the overall work amount is therefore 60% for me and 40% for my co-author. *Chapter 4* has also benefited substantially from many anonymous referees in the process of submission to Technology Forecasting and Social Change Journal (TFSC). Five sections of *Chapter* 4 - the introduction, the literature review, and the case studies on South Korea, Brazil, and Chile –have been published as:

- Pietrobelli, C., and Puppato. F. (2015) Technology Foresight and industrial strategy, *Technology Forecasting and Social Change*, special issue, forthcoming.

In *Chapter 4*, a new section (4.5.4.) has been included to address the case of Argentina. Such decision was made with the intent to enhance the overall coherence of the dissertation, which primarily addresses the Brazilian and Argentine industrial development. This enabled us to enrich the possible conclusions to be drawn from *Chapter* 4, along with the explanatory power of the overall thesis.

Finally, all chapters have benefited from substantial comments, critics and suggestions from attendants to seminars and conferences at Friedrich-Schiller University of Jena (Germany), Federal University of Rio De Janeiro (Brazil), and the Economic Commission for Latin America and the Caribbean (Chile).

Abbreviations and acronyms

BNDES	Banco Nacional de Desenvolvimento Econômico e Social
CONICET	National Scientific and Technical Research Council (Argentina)
CNIC	Chilean National Council for Innovation and Competitiveness
ECLAC	Economic Commission for Latin America and the Caribbean
FDI	Foreign Direct Investments
FITS	Technological Innovation Fund (Argentina)
FTS	Sectoral Innovation Fund (Argentina)
FONARSEC	Argentinian Sectoral Fund
GVCs	Global Value Chains
IADB	Inter-American Development Bank
ICT	Information and Communication Technology
ISIC	International Standard Industrial Classification
LA	Latin America/n
LAS	Latin American Structuralism
LI	Labour intensive
LIS	Luxembourg Income Study
NEST	New and Emerging Signals of Trends
MCTI	the Ministry of Science, Technology and Innovation (Brazil)
MNCs	Multinational companies
MINCYT	Ministry of Science and Technology (Argentina)
NIS	National Innovation System
NR	Natural resources
R&D/RD	Research and development
RQ	Research question
HP	Hypothesis
S&T	Science and Technology
TF	Technology Foresight
WB	World Bank

Deutschsprachige Zusammenfassung

Diese Dissertation liefert einen neuen Beitrag bezüglich der Untersuchung der Charakteristika der industriellen Entwicklung sowie deren Einflüsse auf die intersektoralen Lohnunterschiede im verarbeiten Gewerbe Brasiliens und Argentiniens. Sie basiert auf einer Zusammenführung der ökonomischen Literatur aus den Bereichen Evolutionsökonomik, Arbeitsökonomik, Entwicklungsökonomik sowie Innovationspolitik. Die Analyse der angesprochenen Dynamiken auf den strukturellen Wandel wird in Kapitel 2 näher untersucht während der Fokus in Kapitel 3 auf dem Einfluss des strukturellen Wandels auf sektorale Lohnunterschiede liegt. Daran anschließend wird in Kapitel 4 untersucht, wie struktureller Wandel in der Praxis – vor dem Hintergrund der Implementierung vorrausschauender Innovationspolitiken – umgesetzt werden kann.

Die Wahl dieses Themenkomplexes resultiert aus der detaillierten Untersuchung der volkswirtschaftlichen Literatur aus dem lateinamerikanischen Raum, wobei sich drei wiederkehrende, und bisher ungelöste, Hauptprobleme ergeben.

Das erste umfasst die noch immer bestehende Schwierigkeit, Produktionsstrukturen von der Spezialisierung auf natürlichen Ressourcen zu lösen, da diese in der Historie volkswirtschaftliches Wachstum behinderten (Torvik, 2002). Innerhalb dieser wenig dynamischen und instabilen ökonomischen Umgebung wird die Herausforderung des strukturellen Wandels zunehmend bedeutsamer. Im Kontext dieser Arbeit umfasst struktureller Wandel die konkreten Anstrengungen, eine gesteigerte Wertschöpfung in das Produktionssystem zu integrieren, insbesondere in Hochtechnologie- und forschungsintensiven Sektoren.

Der zweite Problembereich resultiert aus der seit langem bestehenden Ungleichheit, welche in der Literatur als ein Indikator für persistente Unterentwicklung gilt (Cassiolato et al. 2014). Der lateinamerikanische Raum gilt als eine der Regionen mit der weltweit größten Ungleichheit (Torvik, 2002; Ocampo und Ross, 2011).

Die dritte Herausforderung bezieht sich auf die praktische Umsetzung technologisch-vorrausschauender Politiken ("technology foresight", TF), mit dem Ziel der Stärkung des strukturellen Wandels in Entwicklungsländern. Gegeben deren begrenzte Ausstattung, bezogen auf Technik sowie Forschungs- und Entwicklungsressourcen, sehen sich diese Länder einer zusätzlichen Herausforderung bezüglich des Anschlusses an die Technologieentwicklung gegenüber.

Struktureller Wandels und Lohnungleichheiten sind in den lateinamerikanischen Ländern nach wie vor relevante Themen: Im aktuellen UN-Report „Structural Change for Equality“ aus dem Jahr 2012 sind die Bedenken hinsichtlich einer gerechten Entwicklung zur Erreichung von nachhaltigem Wachstum zusammengefasst (ECLAC, 2012:13). Aus diesem Grund besitzen die genannten Herausforderungen hohe Priorität in den politischen Agendas vieler Entwicklungsländer. Im UN-Bericht wird die Bedeutung von Innovationen sowie die Rolle von Investitionen in forschungs- und wissensintensiven Sektoren zur Steigerung der Wettbewerbsfähigkeit hervorgehoben. Dennoch ist der Verteilungseffekt von Innovationstätigkeiten auf die intersektoralen Einkommensunterschiede bisher wenig erforscht.

Gegeben diese vorherrschenden Globalisierungs- und Wettbewerbsbedingungen ist das Ziel dieser Dissertation, den strukturellen Wandel und die Lohnungleichheiten in einer Zusammenstellung von Studien in drei Kapiteln zu verknüpfen. Die Kapitel 2 und 3 analysieren die industrielle Entwicklung Argentiniens und Brasiliens empirisch. Kapitel 4 umfasst im Zuge einer wirtschaftspolitischen Fallstudie zwei weitere Länder, Chile und Südkorea, um die Implikationen aus den Untersuchungen des strukturellen Wandels aus eher qualitativer Perspektive zu erweitern.

Im Folgenden sollen nun die Ziele, Methoden und Hauptergebnisse der vier Abschnitte der Dissertation detaillierter vorgestellt werden.

Kapitel 2 analysiert, inwieweit struktureller Wandel im verarbeitenden Gewerbe Brasiliens und Argentiniens stattgefunden hat. Dafür wird zunächst die *Richtung* des strukturellen Wandels, in Form der Sektoren, welche denselben vorantreiben, untersucht. Anschließend werden die Dynamiken des Produktivitätswachstums herausgestellt. Den dritten Punkt bildet die Analyse der intrinsischen Eigenschaften – beispielsweise den Grad der *Produktivitätsdispersion*. Abschließend werden die erlangten Ergebnisse vor dem Hintergrund der durchgeführten volkswirtschaftlichen Reformen der beiden Länder interpretiert. Das Hauptziel ist die Herausarbeitung und der Vergleich der Zeitverläufe der industriellen Entwicklung in Argentinien und Brasilien. Diesbezüglich liefert diese Arbeit zusätzliche Instrumente zur Bewältigung der Herausforderungen bezüglich der ökonomischen Entwicklung Brasiliens und Argentiniens: Der Versuch, die Produktionsstruktur zu diversifizieren, weg von einer Fokussierung auf natürliche Ressourcen (sogenannte „Dutch Disease“), mit dem Ziel, nachhaltiges Wirtschaftswachstum zu generieren.

Die *Richtung* des strukturellen Wandels, d.h. die Verschiebung der Ausrichtung der industriellen Produktion auf forschungsintensivere Sektoren, kann als der Anteil des Wertschöpfungsbeitrages der forschungsintensiven Industrien an der gesamten Wertschöpfung des verarbeitenden Gewerbes ausgedrückt werden (Cimoli et al., 2006).

Die *Dynamiken* des strukturellen Wandels werden mithilfe der Produktivitäts-Zerlegungs-Fomel (Cantner und Krüger, 2008) untersucht, welche das gesamte Produktivitätswachstum in drei Teile aufgliedert: Die "within", „between" und die „covariance"-Komponente (siehe Kapitel 2 für nähere Angaben). Hierdurch kann der Anteil des Produktivitätswachstums, der durch den strukturellen Wandel induziert wird, bestimmt werden (ausgedrückt durch die between Komponente).Die Analyse beruht auf dem Selektionsprozess der Sektoren, welche verschiedene Technologien wählen. Das Wachstum der Sektoren hängt von deren Erfolg relativ zu den Wettbewerbern ab, wobei das Ergebnis unter Umständen die technologische Entwicklung determiniert, welche sich wiederum aus den best practice der verarbeitenden Industrien zusammensetzt. Die bereits genannte Formel wird verwendet, um die Relation von Produktivität und Output zu bestimmen (stellvertretend für den Marktanteil).

Die Produktivitätsdispersion wird anhand der Produktivitäts-Varianz innerhalb (within) der Makro-Sektoren gemessen, wobei diese aufzeigen, ob Sektoren die aufgrund moderner Technologien eine hohe Produktivität aufweisen, gleichzeitig mit weniger produktiven Sektoren nebeneinander bestehen. Eine solche heterogene Produktivitätsstruktur ist ein typisches Merkmal von Entwicklungsländern.

Die Ergebnisse zeigen auf, dass die beiden Länder anhand von zwei Modellen für Produktion und strukturellen Wandel differenziert werden können. Die Industrie Argentiniens ist durch die vorwiegende Nutzung natürlicher Ressourcen charakterisiert; dies wird daran deutlich, dass die Fähigkeit strukturellen Wandel einzuleiten einhergeht mit der höchsten Wertschöpfung. Demgegenüber zeigt die industrielle Struktur Brasiliens eine deutlich höhere Dynamik zugunsten forschungsintensiver Industrien, welche in diesem Fall ebenfalls einen Einfluss auf die Einleitung strukturellen Wandels hat. In beiden Ländern zeigen Industrien die auf natürlichen Ressourcen basieren (im Gegensatz zu arbeits- oder forschungsintensive Sektoren), die höchste Produktivitätsdispersion, was ein Zeichen wirtschaftlicher Rückständigkeit, resultierend aus geringer technologischer Verbreitung.

In Kapitel Drei wird untersucht, inwieweit struktureller Wandel intersektorale Einkommensunterschiede in den verarbeitenden Industrien Argentiniens und Brasiliens beeinflusst, wobei argumentiert wird, dass die Sektorspezialisierung ein Schlüsselelement zur Erklärung solcher Prozesse darstellt. Dies wird durch die Verknüpfung der Literatur zur Evolutions- und Arbeitsmarktökonomik in einer neuen, ergänzenden Form erreicht, um die Ursachen für

Einkommensunterschiede aus makroökonomischer Perspektive besser erklären zu können. Das Verständnis der Dynamiken strukturellen Wandels (Kapitel 2), zusammen mit dessen Auswirkungen auf die Lohnungleichheit (Kapitel 3), erlaubt die Formulierung von Politikempfehlungen hinsichtlich einer dynamischeren, nachhaltigen und gleichmäßigen industriellen Entwicklung. Insbesondere untersucht die Studie, ob und in welchem Ausmaß Beschäftigte von sektoralen Lohnprämien aufgrund von Produktivitäts-, Bruttogewinn- und Handelsdynamiken (Repräsentanten strukturellen Wandels) profitieren können. Zusätzlich wird ermittelt, ob sich diese Effekte, abhängig von den Makro-Sektoren in welchen die Arbeiter beschäftigt sind, signifikant unterscheiden.

Eine gründliche Literaturanalyse zeigt Forschungslücken in der Evolutionsökonomik auf hinsichtlich des Verteilungseffektes durch Strukturänderungen – insbesondere aus sektoraler Sicht. Obgleich der Entwicklung von Ungleichheiten auf Länder-, Haushalts- und Berufstätigen-Ebene in der Literatur große Aufmerksamkeit zukommt, ist es bisher nicht gelungen, die Ursachen für sektorale Lohnunterschiede zu erklären. Um dies zu erreichen, betrachten wir zunächst genauer die Daten und Methoden zur Messung von Lohnzuschlägen auf Industrieebene. In einem zweiten Schritt untersuchen wir, welche Kanäle des Strukturwandels bezüglich der Produktivität, Bruttogewinnmargen und Handelsdynamik – namentlich der Importanteil sowie der Öffnung des Handels – den größten Einfluss auf die Bildung sektorübergreifender Lohnzuschläge ausübt. Nach der Ursachenbestimmung der intersektoralen Einkommensunterschiede untergliedern wir, drittens, deren Effekte auf Makroebene. Dies soll das Verständnis davon, ob der sektorale Charakter dieser Industrien einen Einfluss auf die Bildung von hohen oder geringen Lohnzuschlägen hat, verbessern. Die Ergebnisse verdeutlichen, dass Handelsdynamiken innerhalb von forschungsintensiven Industrien als Katalysator für die Bildung hoher sektoraler Lohnprämien wirkt. Andersherum verhält es sich in Industrien die auf natürlichen Ressourcen basieren. In einer gemeinsamen Untersuchung beider Länder sowie einer Einzelanalyse Brasiliens zeigen wir, dass die sektoralen Lohnprämien wachsen wenn struktureller Wandel mittels Handelsdynamiken in forschungsintensiven Industrien fungiert. Für Industrien welche auf natürlichen Ressourcen basieren ist das Gegenteil der Fall. Diese Ergebnisse bestätigen die Hypothese, dass forschungsintensive Industrien, welche dynamischer sind und wahrscheinlich höher gebildete und rechtlich stärker geschützte Arbeiter beschäftigen, einen relativ geradlinigeren Wirkmechanismus für strukturelle Umwälzungen bezüglich größerer Lohnprämien aufweisen, wovon wiederum die Beschäftigten profitieren. Solche positiven Effekte resultieren zum Einen aus Handelsoffenheit, welche größere Handelsmöglichkeiten, eine höhere Produktion und damit höhere

Gehaltsprämien ermöglicht, und zum Anderen aus dem Importanteil – vermutlich weil Importe bei forschungsintensiven Industrien einen Komplementär- und keinen Substitutions-Charakter hinsichtlich inländischer Produkte aufweisen.

Der Umstand, dass das separate Modell für Argentinien – mit Ausnahme der gelaggten Werte der abhängigen Variable selbst – keine signifikanten Ergebnisse liefern konnte, ist ein signifikantes Ergebnis dafür, dass in Argentinien anzunehmend andere Faktoren wie bspw. die institutionellen Bedingungen, externe Schocks und Krisen, wie jene Finanzkrise von 2001 etc., jene Faktoren reduziert haben, die stark mit strukturellem Wandel zusammenhängen.

Kapitel Vier untersucht aus innovationspolitischer Perspektive, wie technologisch-vorrauschauende, politische Maßnahmen Entwicklungsländer bei dem Streben nach strukturellem Wandel unterstützen können. Vorausschauende Ansätze, angewendet auf globaler Ebene, werden zunehmend zur vorherrschenden Entwicklungsrichtung, insbesondere für Entwicklungsländer die einem Zustand mit geringer Entwicklungsrate, der sog. "low development trap" (Cimoli und Katz, 2003; Sturgeon und Gereffi, 2013), entkommen wollen. Zu diesem Zweck, können technologisch-vorrauschauende Ansätze durch den systematischen und langfristigen Blick auf wissenschaftsbasierte Technologie und Innovation (S&T), konkret zu umfassenderen, wirtschaftspolitischen Entscheidungen beitragen (Irvine und Martin, 1984). Kapitel 4 befasst sich mit dieser zentralen Fragestellung und analysiert, inwieweit von technologischer Vorausschau geprägte Prozesse einen Bestandteil von Strategien auf Industrieebene darstellen, indem zunächst die zugrundeliegende Theorie aufgearbeitet und diskutiert wird und anschließend vier Beispiele aus vier verschiedenen Ländern analysiert werden. Als erstes werden wir den Fall eines sich aktuell entwickelnden Landes, Südkorea, untersuchen, welches als Best-Practice-Referenz fungiert, da hier eine Kombination aus kluger Industriepolitik und vorausschauender Vision auf nationaler Ebene eindeutig zur Erreichung eines klar formulierten und einzigartigen hohen ökonomischen Wachstums beigetragen hat.

Zweitens untersuchen wir den Fall Brasiliens, bei welchem die Zusammenführung und gemeinsame Umformung von Industriestrategien und technologischer Vorausschau eindeutig die Fähigkeit des Landes demonstriert, neuartige Dynamiken globaler Wertschöpfungsketten zu verstehen. Anschließend konzentrieren wir uns auf die institutionelle Entwicklung eines anderen Entwicklungslands, Chile. Chiles Regierungsinstitutionen haben einen institutionellen Rahmen geschaffen, welcher durch das "National Council for Innovation and Competetiveness" (CNIC) verkörpert wird, welches die enge

Kohärenz von Industriestrategien und langfristiger Technologie-Vorausschau unterstützt. Abschließend betrachten wir die Rolle der technologischen Vorausschau in einem weiteren Entwicklungsland, Argentinien, welches konträr zu Südkorea, ein kontrafaktisches Fallbeispiel darstellt. Dieses verdeutlicht, wie instabile und volatile makroökonomische Umweltbedingungen die Bildung einer fruchtbaren Umgebung, in welcher sich technologisch-vorausschauende Ansätze erfolgreich entwickeln und durchsetzen können, verhindern können, und demnach auch keine gemeinsames Bestehen von technologisch-vorausschauende Wirtschaftspolitik und Industriestrategien gegeben sein können. Wir empfinden den Fall Argentiniens, verglichen mit den vorhergehenden Beispielen, als besonders lehr- und aufschlussreich, da es die Bedeutung makroökonomischer Wirtschaftspolitik für den Erfolg bzw. Nichterfolg von technologisch-vorausschauenden Ansätzen unterstreicht.

Zum Schluss werden in Kapitel 5 die wichtigsten Forschungsergebnisse der Dissertation sowie die geleisteten Beiträge aber auch deren Einschränkungen zusammengefasst. Insbesondere wird dabei deutlich, wie die erzielten Resultate ein gemeinsames Ganzes bei der Klärung unserer Forschungsfragen schaffen, welche darauf abzielen eine fundierte Basis dafür zu schaffen, Innovation in eine Richtung zu leiten, die Ungleichheiten reduziert aber umgekehrt auch Ungleichheiten als Ausgangspunkt für die Förderung von Innovationstätigkeiten zu machen. Tatsächlich haben wir herausgefunden, dass struktureller Wandel in Form von Handelsoffenheit und Importanteilen innerhalb von forschungsintensiven Industrien die Gehaltsprämien erhöht. Zudem sind die sektoralen Löhne bei solchen Makro-Sektoren gleichmäßig verteilt. Somit sind Bestrebungen, die Ressourcen von traditionellen, auf natürlichen Ressourcen beruhenden Industrien, auf technologieintensivere zu verschieben, von höchster Wichtigkeit. Technologisch-vorausschauende Wirtschaftspolitik sollte den Sektor-übergreifenden Angleichungsprozess der Einkommensallokation unterstützen, indem Optimierungen und Verbesserungen der bestehenden Entwicklungsmöglichkeiten sowie ein systematischer Ansatz bei der Implementierung von Innovationspolitik, gefördert werden.

1. Introduction, Aims, Outline

1.1. Introduction

By combining different strands of literature – evolutionary, labour, development economics and innovation policy - this thesis provides a novel contribution to examining the patterns of industrial development and their effect on cross-sectoral wage inequality in the Brazilian and Argentine manufacturing sectors. The highlighted dynamics will focus on structural change (*Chapter 2*), the impact of this on wage inequality (*Chapter 3*), and how structural change can be achieved in practice thanks to the adoption of foresight innovation policies (*Chapter 4*).

The choice of this topic stems from a detailed study of the Latin American[1] (hereinafter referred to as 'LA') economic literature where three major recurrent – and as yet unresolved - issues emerge.

The first is the on-going difficulty to shift production structure away from a secular specialization in natural resources – which historically prevented growth - (Torvik, 2002). Despite the fact that large endowments of natural resources – a common feature of Brazil and Argentina - can arguably provide vast opportunities for countries to develop, the actual effect of natural resources wealth on economic development is still object of vast debate among economists. The mere exploitation of natural commodities tends to shift factors of production away from the more dynamic, R&D and technological intensive sectors (Cimoli *et al*., 2006). Within this low dynamic and especially vulnerable setting, the challenge of *structural change* becomes more prominent. The capacity of a country to shift its resources towards sectors with higher value added can enhance the potential to generate productivity growth and/or improvement of product quality while enabling an in-depth diversification of the economy. In this thesis, structural change is understood as the concrete effort to integrate higher value added in the production system, particularly in R&D/technological-intensive sectors. This changing trajectory is especially important for developing countries: given their lower levels of technological development, they face remarkable constraints to catch up with more developed economies (Lall, 2004).

The second issue originates from the long-lasting *inequality* which represents one of the most deeply rooted features of under-development (Cassiolato *et*

[1] LA's definition includes the 20 states in Latin America plus the 13 states in the Caribbean and in this thesis it is often referred as "the region".

al., 2014) whereby LA is well-known for being one of the world's most unequal regions (Torvik, 2002, and Ocampo and Ros, 2011). The lack of transparency and the intrusive scope of industrial and trade reforms on the region have been often deemed responsible for such social/economic setting. Additionally, the scarce diversification of the economy – and the consequent need to gear structural change - appears to be deeply intertwined with issue of wage inequality. Countries that are well endowed in natural resources tend to grow less and suffer from higher income inequality than other economies (Sachs and Warner, 1995). Natural resources' production process tends to be high-capital- but low-skill-intensive, discouraging local investments in R&D and education, with a negative impact on R&D and engineering investments/activities resulting in a "low development trap" (Cimoli and Katz, 2003). The endowment and commercialization of a natural resource is likely to be remarkably centralized due to the facility with which mineral rent can be "captured by predatory national elites for their own wealth accumulation" (Cornia, 1999:10).

The third challenge relates to the practical implementation of technology foresight (TF hereafter) policies in order to promote structural change in developing countries, that given their scarcity of technological and R&D endowment face additional constraints with respect to developed countries to reach the technological frontier. Developing countries' "vulnerability" (Ascher, 2009), denotes their lack of propensity to take even the most moderate risk, due to the tendency to increase discount rate and valuing the future benefits as low. Typically, this risk aversion is exacerbated in highly unstable/volatile macro-economic environments. This condition calls for a renewed attention to the way TF policies can be identified and implemented, whereby a foresight – and not opportunistic - behaviour is deemed essential. The interdependencies emerging from a globalized competitive setting makes it imperative to devise and follow an appropriate "strategy" to orchestrate responses from the government, the private sector, and research organizations (Lall, 2004). Besides, the rapid expansion of internationally integrated production systems – or Global Value Chains (GVCs) - intensified rather than diminished LA countries' specialization in natural resources intensive industries of which they are abundantly endowed.

Remarkably, the questions of structural change and wage inequality in LA remain as relevant as ever before: the latest UN framework "Structural change for equality" (2012) precisely manifests a deep concern for an equitable development in order to pursue "sustainable growth" (ECLAC, 2012:13). Therefore these two defining challenges are placed at the top of many developing countries' policy agendas. Indeed, the wider relationship between growth and inequality has puzzled economists for centuries (Kuznets, 1995; Torvik, 2002, and ECLAC, 2012). Is it more important to pursue economic growth, or to focus on how the gains of such growth are actually distributed? The UN framework acknowledges the relevance of innovation to promote competitiveness precisely by investing in R&D and knowledge intensive sectors. However, the distributive effect of innovative activities on cross-sectoral wage gaps still remains largely underexplored. The implementation of innovative activities should be fostered in a way that can help to tackle the inequalities generated by a highly polarized production system. The mere exploitation of natural resources alone should not constitute the only value added of the economy. Given this prevailing globalized context and the new windows of opportunities it brings about, this thesis fills these gaps, by providing a novel perspective for policy makers to better understand not only structural change dynamics and policies, but also the way in which structural change affects - the already high - inequality, from a macro-economic/evolutionary perspective.

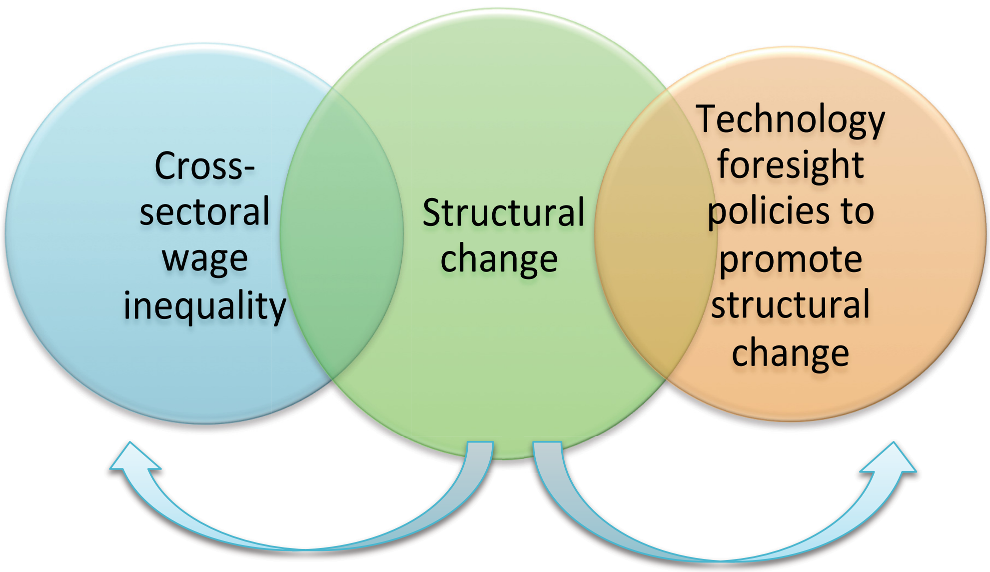
The main goal of this thesis is to link structural change and wage inequality by collecting a set of studies organized in three chapters. *Chapter 2* and *3* empirically focus on the Argentine and Brazilian industrial development. *Chapter 4* includes additional countries – Chile and South Korea - through a policy-level case study, in order to enrich the conclusion obtained when analysing structural change from a different – more qualitative -angle. Each country has its own characteristics and historical circumstances. However, the conclusions provided by these works emphasize different drivers and mechanism underpinning structural change, which might be applied to other developing countries, particularly in LA.

More precisely, *Chapter 2* investigates the *direction*, *dynamics* and *productivity dispersion* of structural change to provide an insight into its evolution and dynamics. The *direction* of structural change is measured through the shift of industrial value added towards more R&D-intensive sectors; the *dynamic* of structural change is examined through a productivity decomposition analysis, in order to reveal the sectors that most notably trigger - or fail to trigger - structural change; and the *productivity dispersion* of structural change is calculated as the variance of productivity levels across sectors.

Chapter 3 builds on the findings from *Chapter 2* and assesses whether, and if so, to what extent, structural change affects cross-sectoral wage inequality. The analysis emphasizes the nature/typology of the industrial sectors, arguing that economic specialization is a key element in explaining such process. As a complement of the previous two chapters, *Chapter 4*, by embracing a policy perspective, asks how TF exercises can help developing countries to pursue growth and structural change in practice (see Figure 1.1. for a graphical representation of the overall thesis' structure). In the remainder of the present chapter a roadmap of the thesis is provided. Section 1.2 explains the data and main sources of information that have been used in order to answer the research questions. Then, section 1.3, illustrates the theoretical and methodological background of the three core chapters of the thesis. Section 1.4. describes the key features of the historical context in Brazil and Argentina, while providing the justification behind the choice of these countries. Finally, section 1.5. presents the outline of the thesis, highlighting the key issues, the main objectives as well as findings.

Figure 1. 1

Overall thesis framework



1) How and to what extent did structural change occur in the Argentina and Brazilian manufacturing sector? (*Chapter 2*)

2) How does structural change impact cross-wage inequality? (*Chapter 3)*

3) How can structural change be achieved in practice thanks to the adoption of technology foresight policies? (*Chapter 4*)

Source: own elaboration based on the literature review.

1.2. Data

Chapter 2 and *3* of this thesis are based on the Analysis Program of Industrial Dynamics database (PADI) (Katz and Stumpo, 2001). PADI covers 28 manufacturing sectors spanning 38 years, from 1970 to 2007, classified according to the International Standard Industrial Classification (ISIC rev. 3) for Brazil and Argentina. The 28 industrial sectors can be grouped into three main macro-sectors[2] according to the most used factors of production, namely:

- natural resources (NR) intensive industries: 13 sectors;
- labour intensive (LI) intensive industries: 10 sectors; and
- R&D intensive industries: 5 sectors.

The sub-specification of each macro-sector is illustrated the table below.

Table 1. 1.

PADI: sectors' classification NR, LI and R&D intensive industries (macro-sectors) (3-digit ISIC sectors classification Cimoli *et al.*2006)

ISIC	Macro-sector	Industrial sector	ISIC	Macro-sector	Industrial sector
311	NR	1) Food	341	NR	15) Paper and paper products
321	LI	2) Textiles	351	NR	16) Industrial chemicals
322	LI	3) Clothing	353	NR	17) Petroleum refineries
323	LI	4) Leather and leather products	354	NR	18) Coal products
324	LI	5) Footwear	355	NR	19) Rubber products
332	LI	6) Furniture	362	NR	20) Glass and glass products
342	LI	7) Printing and publishing	369	NR	21) Non-metallic mineral products
352	LI	8) Other chemical products	371	NR	22) Iron and steel
356	LI	9) Plastic products	372	NR	23) Non-ferrous metals
361	LI	10) Pottery	381	R&D	24) Metal products
390	LI	11) Other manufacturing industries	382	R&D	25) Machinery except electrical
313	NR	12) Beverages	383	R&D	26) Electrical machinery
314	NR	13) Tobacco	384	R&D	27) Transport equipment
331	NR	14) Wood and wood products	385	R&D	28) Professional and scientific equipment

Source: own elaboration on the base of PADI - UN, ECLAC.

[2] For the classification, refer to Cimoli et al. 2006. Here the term "macro-sector" is the same as the concept of "sector" in the paper of Cimoli *et al.* (2006:31). However, in the current work the terms "sector" and "industry" are used interchangeably to indicate the 28 sectors composing the whole manufacture of the country.

Such division is crucial since it enables understanding of whether the characteristics of structural change along with their impact on inequality, varies in relation to the macro-sector in which they occur.

R&D intensive industries, due to their most intensively used factor of production – R&D - can be regarded as the most technologically intensive ones (Cimoli, *et al*., 2006 and Katz, 2001).

The database contains aggregated data for 28 manufacturing sectors at constant prices (1985 as base year) for a number of variables, among which those that will be included in the thesis are:

- imports (million US$, current prices);
- exports (million US$, current prices);
- gross output (the sum of the value of goods produced in the country, including the value of intermediate goods used in the production, million US$,
- employment (number of people);
- value added (given by the gross output minus the value of inputs, million US$, constant prices);
- productivity (output produced per unit of labour input US$, constant prices);
- wages (million US$); and
- gross margin (the gross profit of enterprises measured as the difference between revenue and fix as well as variable costs of production, excluding administration, sales and R&D costs, million US$, constant prices).

Chapter 4 is based on a qualitative approach combining and interpreting information obtained from public reports, independent evaluations, interviews with key experts, as well as information included in the press.

1.3. Theoretical and methodological background

Chapter 2 and *3* of this thesis, share a common theoretical background embracing the Schumpeterian and Latin American Structuralism (LAS) tradition of studying industrial evolution with a dynamic approach. These two literatures, falling under the umbrella of evolutionary economics, serve as a backbone to provide a novel framework to examine and compare the industrial development trajectories of the Brazilian and Argentine industrial development.

In addition, since *Chapter 3* explains the causes of wage inequality, we made an additional effort in linking the evolutionary and the labour market literatures, in a new and complementary fashion to explain the causes of wage inequality from a macro-economic perspective.

Chapter 4, by adopting an innovation policy approach, builds on the technology foresight and GVCs literatures, since its main goal is to reveal how and to what extent technology foresight and industrial strategies are – and must be - mutually consistent to facilitate the complex process of structural change.

Below we provide more detailed insights concerning these literatures used for the theoretical and empirical approach of the three core chapters.

The suitability of the Schumpeterian and LAS literatures in providing the theoretical foundation for *Chapter 2* addressing structural change dynamics, stems from its emphasis on the *sectoral* nature of economic development. Such process should result from resources' shifting from primary to more dynamic sectors, typically characterized by R&D and technology intensive industries (Cimoli *et al*., 2006).

The explicit link between structural change and innovation is best epitomized by the concept of "creative destruction" coined by Schumpeter (1942). This refers to the disruptive effect of the technological progress on older technologies and/or ways of production. Economies are not in a static equilibrium, but are rather continuously disrupted by technological improvements.

LAS, pioneered by Prebisch (1950), while recognizing the centrality of innovation for development, placed greater emphasis on the structure of the economies which are regarded as inherently asymmetrical. The usual adopted setting is a dual model made up by "the centre" (or developed economy) and "the periphery" (or underdeveloped economy), the latter being representative of Argentine and Brazilian positioning in the international economy. On the one hand, the centre economies - made up by highly productive or leading sectors - tend to specialize in industrial production and are thus much more complex and diversified (Cimoli and Porcile, 2011). On the other hand, the production structure of the periphery - made up by the subsistence sector - is inherently based on agricultural and primary products, wherein a shortage of savings and a low rate of capital formation are conducive to a lower standard of living (Jamenson, 1985). Such low production diversification can be perceived as the direct outcome of unequal capital and technological penetration, resulting in a mono-specialization that feeds the vicious circle of poor growth, underemployment and unequal income distribution. According to LAS, structural change can be viewed as the process by which investments are geared towards the generation of intermediate - between the subsistence and the frontier sectors - and higher productive sectors, facilitating the developing countries' challenge to find a way out from their "peripheral" condition.

The adoption of evolutionary literature is based on its suitability in addressing the underlying macro-economic factors responsible for the persistent asymmetries and complexities in the production structure and capabilities that ultimately generate cross-sectoral inequality (Cimoli *et al*., 2006). Yet, by adopting solely an evolutionary framework, some specific dynamics regarding the actual *causes* of wage inequality are overlooked and in turn better explored by the labour market literature. The added value of *Chapter 3* lies precisely in the ability incorporate the useful insight from the labour market literature to complement and improve the explanatory power of the evolutionary theory in common with *Chapter 2*. In such a way we fill some major literature gaps both from the evolutionary and the labour market perspective.

Labour economics benefits from a more consolidated focus on the actual causes of inequality which can be divided into those related to the demand and the supply of labour. *Chapter 3*, will mainly build upon the former group investigating the role of technology (Acemoglu, 2002, Howell and Wieler 1998, Card and DiNardo, 2002 and Katz and Autor, 1999 and Caselli, 2014) and trade (Wood, 1994, Corsini, 2013 and Sampson, 2014). The inequality examined in *Chapter 3*, is called *between-sector* or *cross-sectoral wage inequality*, since it accounts for the dispersions of average wages by sector with respect to the median wage of the macro-sector to which the sector belongs. This measure of inequality comes with pros and cons. The pros lies in the capacity grasp how structural change impacts wages from a sectoral perspective. Are those sectors propelling structural change more likely to generate higher (or lower) average wage gaps? (*i.e.* is structural change driven by a diversification of the production structure towards more R&D or NR intensive sectors? And how are averages wages per worker distributed across the these macro-sectors?). The issue is not trivial since the answer to this question can offer policy makers an overarching macro-economic outlook as to what direction is the economy actually taking. Hence, the type of inequality addressed *Chapter 3*, conceptually differs from *within-sector* wage inequality, which is the one typically examined in the labour market literature. *Within-sector* inequality focalizes on workers' characteristics - including age, gender, education, etc. - and therefore it assumes a worker perspective. Our results should not be confused with the dispersion of personal wages, since data at a worker level in the industrial sector for such a long time frame is, unfortunately, not available. Whilst recognizing the limits of the current study in the impossibility to address the *within-sectoral* causes of wage inequality, we are also aware the importance of a macro-economic understanding of how inequality actually occurs at a sectoral level and for a relatively long time frame (38 years). From a policy perspective one important challenge is to gear innovation in a direction that reduces inequality, and to make inequality a starting point to spur innovation effort. A macro-economic/sectoral understanding of the relationship between structural change and wage inequality allows the configuration of different policy options for development alternatives aspiring towards a more equitable growth trajectory.

Chapter 4 explores from an innovation policy point of view, how structural change can be achieved in practice through foresight policies in developing countries that, given their scarcity of resources and lower levels of technological development, face additional constraints with respect to developed ones in the adoption of R&D intensive technologies or products. To this end the chapter delves into the theoretical foundations of innovation and TF policies in combination with the industrial and GVCs literatures. TF, by encouraging the adoption of a systematic approach in looking into the longer-term future of science technology and innovation (S&T), it can concretely help making better-informed policy decisions (Irvine and Martin, 1984). The analysed case studies highlight how industrial and TF strategies need to be mutually consistent, and their link needs to be taken seriously, coherently designed and implemented in light of its role to shape and economic growth.

Depending on the research questions and the availability of data in each chapter, different quantitative econometric and qualitative research methods are applied. The first two empirical chapters include a productivity decomposition (Cantner and Krüger, 2008), a fixed-effect panel estimation and a Generalized Methods of Moments with Arellano Bond. The last qualitative chapter adopts a case study approach. In fact, whilst statistics and econometric regressions allow for inference of causality, a qualitative method warrants a closer, and therefore more articulated, examination of structural change related policies' processes and mechanisms.

1.4. Argentina and Brazil historical background

This section summarizes the historical context surrounding Brazil and Argentina, an essential step to appreciate the social and economic transformations featuring their economic/industrial development. In so doing, it supports the contextualization, while and enhancing the policy relevance, of the obtained results as well as provides the justification behind the choice of these two countries and their manufacturing sector.

Both Argentina and Brazil experienced remarkable changes in the last decades. The countries moved along specific development trajectories with their own features, issues, failures and challenges. Brazil is historically well known for being one of the most unequal countries and yet the most dynamic within Latin America[3] - proved by its fast economic growth due to its significant development opportunity, its potential for investment hub, and the presence of a huge market. Argentina, used to be one of the most egalitarian countries, at least up until the trade liberalization period, and more recently has been severely hit by political turmoil and financial default such as the one in 2001 resulting from a structural macro-economic instability. This poor socio-institutional setting clearly undermined Argentine's generation of a solid and sustainable industrial development, despite its initial favourable assets including natural resources, the generation of capital institutions, massive European immigration and solid ties with international markets (Pineda, 2009).

Nevertheless, some commonalities in terms of economic policies and crisis are shared by both countries' experiences (see Boxes 1.1. and 1.2. and Figure 1.2. for a graphical representation of the historical periods), namely:

- The Import Substitution Industrialization (ISI) period took off approximately around the 1950s until the end of the 1970s, depending on the country. It involved a remarkable public intervention in the economy, largely financed through foreign debt, subsidies and tariff barriers aimed at substituting imports by domestic production, which strengthened remarkably (Cornia, 1999). ISI's main goal was to spur the accumulation of technological capabilities through an interventionist institutional setting. These protectionist measures helped maintaining the manufacturing sector relatively sheltered from external competition and while reducing the technological gap with the frontier (Cimoli *et al.*, 2014).

[3] As it belongs to the "BRIC countries" - Brazil, Russia, India, China, and South Africa.

- The debt crisis of the 1980s led to a period of recession that lasted approximately until the beginning of the 1990s. This period revealed the unsustainability of the previously chosen model, to finance economic development with external savings, which practically translated into long-term lending by foreign banks subject to flexible interests rates (*ibid*).
- The 1990s witnessed the implementation of a set of neoliberal policies that were opposite in their nature to those of ISI. Such policies aimed at promoting deregulation, privatization, open trade and liberalization of the financial flows, whereby the role of the State was largely downplayed by free market dynamics. Ocampo and Ros (2011) refer to this period as an:

> "…event that led to a reversal of the previous consensus on the development strategy and to a new conventional wisdom which viewed government as an obstacle to development, the private sector as the leading actor, trade as the engine for growth, and foreign direct investment as a priority" (Ocampo and Ros,2011:16).

The paradox is that during trade liberalization productivity growth for most of LA countries accelerated, while the specialization patterns tended to move towards low-tech industries (Cimoli *et al.*, 2014). During this period LA's main competitors were the newly-industrialized and low-income East Asian countries that boasted a comparative advantage in low-skilled manufacturing. Such competitive pressure further reinforced both the Brazilian and Argentinian specialization in natural resource-intensive industries and the "spurious" growth which was merely based on favourable terms of trade or exchange rate of the natural commodities being exported (Furtado, 1961 and 1966).

Despite similar reforms experienced by both countries, two major differences deserve to be highlighted.

The first is that Brazil has demonstrated to be more committed to industrial development than Argentina. In Brazil the ISI period lasted throughout the 1970s and industrial diversification has been sustained by a significant push thanks to the Second National Plan of Development (IIPND). Conversely, Argentina interrupted ISI - and all the instruments of industrial development it brought about - in the late 1970s, by endeavouring a bold and early attempt of trade liberalization (Cimoli *et al.*, 2014).

The second dissimilarity lies in the different use of the exchange rate policy (Novick and Tomada, 2007). After the 1990s, Argentina adopted a fixed exchange rate that led to the greatest social and economic crisis in its history in 2001 (Cimoli *et al*., 2014). By contrast, Brazil implemented a band of fluctuation for the nominal exchange rate which provided more freedom to devalue and readily react to external shocks (*ibid*).

The choice of the manufacturing (or industrial) sector as unit of observation of structural change is conditioned to four motivations. The first is the strong link between industrial development and catch-up in relation to the rest of the world. In Latin America, efforts towards economic development translated into development policies targeting precisely the industrial sector (Cimoli *et al*. 2014). The industrialization process became the dominant development paradigm in the post-war years in order to catch up and promote structural change. The second lies in the importance of the industrial sector as the focus of learning as well as generation, accumulation and diffusion of technological knowledge to the entire economic system. The rising share of technology-intensive activities in manufacturing can be a good proxy for the learning process of the whole economy (Cimoli *et al.*, 2014:81). The third reason relates to data availability. Data on the industrial sector for Argentina and Brazil are readily accessible and boast an extended time series (38 years, from 1970 to 2007) which is key to studies on structural change.[4] A direct implication from the above, is the possibility to perform cross-countries comparisons. Finally the forth motivation is the sector's relative importance within the national economy. The industry represents a considerable part of the production system as observed from its foundation through to its thriving. In fact, despite the fact that, from the late 1980s, the service sector has gained weight relative to the industrial one, the new practices of reshoring, offshoring and industry 4.0 have provided the industrial sector with a renewed prominence. Nowadays the industrial production continues being

[4] The risk is that identifying changes in a small time frame can be misleading. Take for example the case of Argentina's financial default in 2001. In correspondence of this year and the two years after economic figures such as exports, wages, and productivity, are characterized by the most negative fall ever reached in the country. Identifying a structural change in this period can be misleading as it is not easy to isolate say the productivity change from the financial turbulence experienced in those years. In this regard Marchal (1955) argued that:

> "…But if these structural effects are discovered and utilized in the short-term analysis they are not explained therein. It is therefore the role of long-term analysis to appraise not only the consequences, but also the causes of structural tensions. In a long period structural changes become themselves perceptible for the economic subject." (Marchal, 1955:1).

the commanding heights of technological generation and diffusion (see Brettel, *et al*. 2014).

Box 1. 1.

Industrial economic history, Brazil

1970-1980. This is the period of ISI, in which industrial and technological policies favoured manufacturing and employment growth, albeit in a context of scarce competitiveness. The goal of these policies was to nurture a set of national industries in key sectors that could eventually compete with more industrialized nations.

1981-1993. The "lost decade" inaugurated a period of recession due to the external debt crisis that endured until early 1990s.

1994-2003. "Plan Real" and trade liberalization. Defensive rationalization was the most implemented strategy for industries that needed to enter in fierce competition with the international market (Cimoli *et al*. 2014). As we shall see later from our results, in Brazil such defensive rationalization did not have the same dramatic consequences as in Argentina (*i.e.* during this period employment actually increased).

2004-2007**.** Period of commodity boom, whereby exports rose remarkably especially in NR intensive industries.

Source: own elaboration based on Holland and Porcile (2004) and Cimoli *et al*. (2014).

Box 1. 2.

Industrial economic history, Argentina

1970-1975. ISI was implemented through a set of protectionist measures to keep the manufacturing sector sheltered from external competition.

1976-1981. Early bold attempt of trade and financial liberalization which translated in a period of defensive industrialization. The country dismounted most of the policy instruments adopted during ISI and its Welfare State. This resulted in a progressive impoverishment of the industrial structure (Katz, 1997). It was also a period in which the capital account was opened. This combined with a strong appreciation of the real exchange rate, led to huge deficits in current account and explosive external debt.

1982-1990. "Lost decade" that cause a dramatic fall of both the value added and employment. The cost of debt compromised growth and investments.

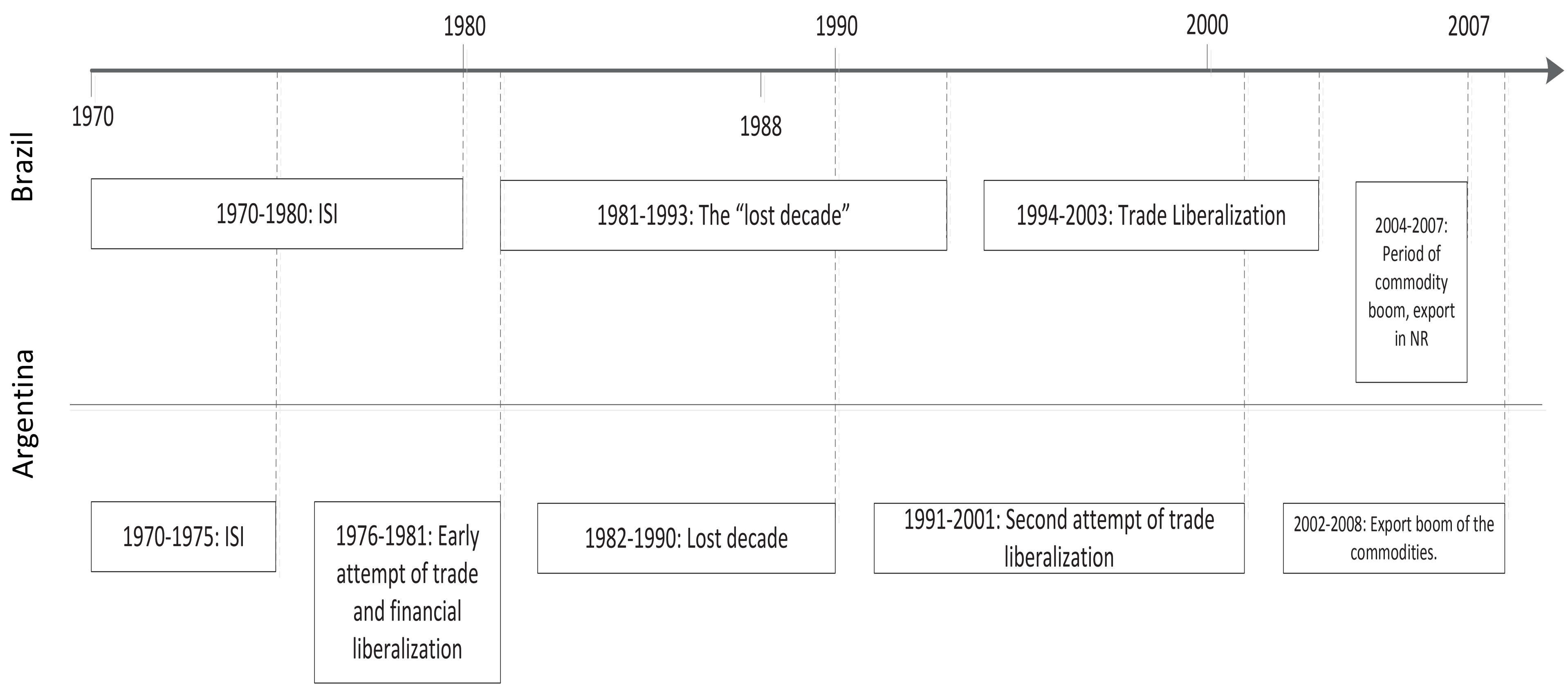
1991-2001. Second attempt of trade liberalization which, similarly to the previous one, was characterized by defensive rationalization. The productive dynamics of this period resulted in a return to static comparative advantages in NR and commodities industries. The Convertibility plan was implemented (fixed exchange rate with the dollar) which led to major overvaluation of the Argentine peso and the financial default in 2001.

2002-2008. Export boom of the commodities. The country sought to rebuild instruments for industrialization and protectionist measures that do not appear to be clearly related to technological learning and catching up (Frenkel, 2004).

Source: own elaboration based on Holland and Porcile (2004) and Cimoli *et al*. (2014).

Figure 1. 2.

Representation of the historical periods of Brazil and Argentina



Source: own elaboration based on Holland and Porcile (2004), Cimoli *et al*. (2014) and

1.5. Outline of the thesis: summary

This section will outline the reminder of the thesis by describing the objective, methods and main findings of the four chapters.

Chapter 2 explores how and to what extent structural change occurred within the Brazilian and Argentine manufacturing industries. First it will examine the *direction* of structural change in terms of sectors propelling it. Second it will disentangle the *dynamics* of productivity growth. Third it will unravel its intrinsic characteristics - such as the level of productivity *dispersion*. Finally it will interpret the obtained results in light of the economic reforms implemented by the two countries. The final goal is to explain and compare the industrial development trajectories in Brazil and Argentina. In doing so the paper provides additional tools to tackle a recurrent challenge undermining Brazil and Argentina's economic development: the attempt to diversify their production structure away from a secular specialization in natural resources (the so called "Dutch disease") to promote a more sustainable and diversified industrial development.

The *direction* of structural change, meant as the shift of industrial production towards more R&D-intensive sectors, is expressed as the share of R&D intensive industries' value added over the total manufacturing value added (Cimoli *et al*., 2006).

The *dynamics* of structural change are analysed through productivity decomposition *formula* using productivity and output as main variables of interest (this latter being used as a proxy for market share) (Cantner and Krüger's, 2008). The *formula* decomposes total productivity growth into three parts: the within, between and covariance component (see *Chapter 2* for further details). This captures to which extent productivity growth is due to structural change (represented by the between component). Sectors' growth depends on their success relative to their competitors. The outcome of this selection process eventually determines the technological frontier which is made up by the few best practices in the manufacturing industries.

The *dispersion* of productivity is measured through the productivity variance within each of the macro-sectors and highlights whether sectors that are highly productive thanks to modern techniques coexist with sectors that are not so productive. A polarized productivity structure appears to be a common feature observed in developing countries.

The results strongly suggest that two distinct models of production and structural change distinguish the two countries.

The first, which is to be found in Argentina, portrays a relatively more pronounced specialization and dynamism in the NR-based sectors, proved by their capacity to trigger structural change along with their top-highest value added. The second model of production, which belongs to Brazil, shows a relatively more pronounced dynamism of R&D intensive industries that showed a gradual but persistent catching up of their value added with respect to the NR intensive ones. At the same time R&D intensive industries in Brazil are the main responsible for triggering structural change. In both countries NR, contrary to LI and R&D intensive industries, display the highest degree of productivity polarization which is symptomatic of economic backwardness resulting from the scant technological penetration.

Chapter 3 examines to what extent structural change affects cross-sectoral wage gaps (or *premiums*) in the Argentine and Brazilian manufacturing industries, arguing that the sectoral specialization of a given industry is key in explaining such a process. It does so by linking the evolutionary and the labour market literatures in a new and complementary fashion better to explain the reasons behind wage inequality from a macro-economic perspective. The understanding of structural change dynamics (*Chapter 2*) along with their impact on earnings inequality (current chapter) allows the formulation of policy advice contributing towards a more dynamic, sustainable and equal industrial development. In particular, the study examines whether, and if so to what extent, workers can benefit from sectoral wage *premiums via* productivity, gross margin and trade dynamics – identified as channels of structural change. Additionally it ascertains whether these effects are significantly different, depending on the macro-sector in which the worker is employed.

A careful review of the literature reveals a lack of studies in evolutionary economics on the distributional impact of structural change, especially from a sectoral perspective. Even though much attention has been paid to inequality trends at the country-, household- and/or worker-level, the literature fails to offer an adequate explanation for the causes of *sectoral* wage gaps.

In order to pursue this goal we firstly explore the data and method to measure industrial wage *premiums*.

Secondly, we investigate which channels of structural change among productivity, gross margin and trade dynamics – import penetration and trade openness - most prominently contribute to the generation of these cross-sectoral wage *premiums*.

Thirdly, once the causes of cross-sectoral wage inequality are identified, we disentangle their effect at the macro-sectoral level. This will allow understanding of whether the sectoral nature of these industries plays a role in generating higher- or lower- sectoral wage *premiums*.

The results indicate that, for both countries jointly considered and Brazil separately considered, trade dynamics in R&D intensive industries appear to act as a springboard for higher sectoral wage *premiums*. The opposite holds true in the case of NR intensive industries. These findings confirm the hypothesis that R&D intensive industries, by being more dynamic, presumably employing more skilled and protected workers, boast a relatively more direct transmission mechanism between structural change and higher wage gaps from which workers can benefit. Such positive effect occurs both through trade openness, by providing more room for higher production and hence higher wage *premiums*, and through import penetration, presumably because imports in R&D industries are likely to be complementary – and not substitutable – to domestic production. The fact that the separate model for Argentina did not provide significant results - with exception to the lagged value of the dependent variable itself - suggests that in Argentina, unlike Brazil, structural-change related factors did not significantly contribute towards the generation of higher wage *premiums*.

Chapter 4, by adopting an innovation policy perspective, analyses how TF policies can help developing countries to pursue structural change. A foresight approach applied on a global scale is increasingly becoming the dominant development paradigm (Sturgeon and Gereffi, 2013), especially for countries wanting to escape and move forward from the “low development trap” (Cimoli and Katz, 2003). To this end, TF by systematically looking into the longer-term future of science technology and innovation (S&T), can concretely support better-informed policy decisions (Irvine and Martin, 1984). This chapter addresses this central question and unravels to what extent TF exercises are essential parts of wider industrial strategies, by first reviewing and discussing the theory and then analysing four examples from four countries. Firstly, we present the case of a now-developed country, South Korea, which serves as a reference for best-practice, where clever industrial policies combined with a foresighted national vision clearly contributed to achieve a well-defined and unprecedentedly fast economic growth. Secondly, we explore the case of Brazil, where the fusion and mutual reshaping between industrial strategies and TF exercises is demonstrating the country’s ability to fully understand the new dynamics of GVCs. Thirdly, we focus on the institutional development in another developing country, Chile. Here the government set up an institutional framework embodied by the National

Council for Innovation and Competitiveness (CNIC) that would appear to favour the coherence between industrial strategy and TF with a long-term perspective. Finally we review the role of TF in Argentina, which contrary to South Korea, serves as counterfactual case study, exemplifying how an unstable/volatile macro-economic environment can inhibit the generation of a fertile environment where TF can flourish. Nevertheless the Argentine government seems to have understood the importance to add opportunities especially to the private sector, by orchestrating a strategic alignment of the NIS´ actors with targeted sectoral perspective/funds.

Finally, *Chapter 5* summarizes the main findings of the thesis along with its major contributions and limitations. In particular it will become clear how the obtained results fit together in explaining our research questions that ultimately seek to provide a solid platform to steer innovation in a direction that reduces inequality, and to make inequality a starting point to stimulate innovation activities. In fact, we found that when structural change acts *via* openness and import penetration in R&D intensive industries, wage *premiums* increase. Furthermore, sectoral wages in this macro-sector are equally distributed, especially in Brazil. Hence, efforts to shift resources from traditional NR industries towards more technological intensive ones are of foremost importance since these sectors not only benefit from a positive transmission mechanism between structural change and wage *premiums*, but such *premiums* are more equally distributed across these sectors (or the R&D macro-sector). Technology foresight policies should help adjustment process of wage distribution across sectors by fostering an improvement in the pre-existing capabilities and a more systematic approach in the implementation of innovation policies.

Chapter 2

2. Structural change and productivity growth dynamics in the Argentine and Brazilian manufacturing sector

Abstract

By drawing on different strands of literature embracing LAS and Schumpeterian economics, this paper provides an original approach to examine and compare the trajectories of industrial development in Brazil and Argentina.

The findings will explain the evolution of structural change, measured both through the shift of industrial production towards more R&D-intensive sectors and a productivity decomposition analysis in order to unravel the sectors that most prominently trigger (or fail to trigger) structural change.

The paper therefore provides additional tools to tackle a recurrent issue undermining Brazil and Argentina's economic development: the attempt to diversify their production structure away from a secular specialization in natural resources (the so called "Dutch disease"), to promote a more sustainable industrial development.

2.1. Introduction

This paper explores how and to what extent structural change occurred within the Brazilian and Argentine manufacturing industries. First by looking at its *direction* in terms of sectors propelling it, second by disentangling the *dynamics* of productivity growth, third by observing its intrinsic characteristics (such as the level of *productivity dispersion/polarization*), and fourth by analysing the obtained results in light of the economic reforms implemented by the two countries. We believe that the insight gained about productivity and structural change dynamics is especially important from an innovation policy perspective for both countries as their economic development *via* structural change represents an uttermost priority (see "Structural change for equality", 2012:13, ECLAC).

It is commonly agreed that economic growth in Latin America (LA) depends on how countries are able to trigger structural change in order to diversify their economies. In fact, it is often the case that their production specialization mainly focuses on the comparative advantage offered by natural resources of which they are abundantly endowed (Cimoli and Katz, 2003). However, in the long term, a radical specialization in natural resources can be counterproductive, since they are by definition finite, with a low local value added and generally employing low-skilled labour force. Thus, structural change by going hand in hand with the diversification of production structure, increasing returns to scale, as well as the generation of new skills, becomes a key factor in generating productivity growth.

In the literature there has been a number of studies addressing structural change. In the current work we will refer and link mainly on to two of them: Holland and Porcile, (2005) to gain a broader picture of the Latin American scenario, and Cantner and Krüger (2008) to deepen the analytical perspective on how to measure structural change. Overall, this work represents an advancement of the state of the art by intentionally focusing on the *sectoral* dimension of industrial development *via* productivity growth dynamics.

To the best of our knowledge based on the reviewed literature there is yet a lack of properly addressing particular issues, such as bridging and building upon traditional measures on productivity growth [5] and productivity heterogeneity in order to explain structural change dynamics on a sectoral level and with a historical perspective. In this work we aim to combine the

[5] Which departs from Fagerberg, (2000) for the work of Holland and Porcile (2005) and Andersen and Petersen (1993) for Cantner and Krüger (2008).

approaches undertaken by the two studies and we will fill in the literature gap in the following manner:

- first, by extending the time frame of the analysis (1970-2007) (whereas in Holland and Porcile (2005) study it goes only until early 2000s), which is key to studying structural change dynamics thoroughly;
- second, by applying a more sophisticated methodology - a modified version of the productivity decomposition *formula* - drawing from Cantner and Krüger (2008) in order to understand in a more detailed manner the drivers of productivity growth. This enables not only to examine the mechanism but also the direction of productivity growth, in line with the LAS literature. We will do so by using productivity and output as the main variables of interest; and
- finally, by focusing on Argentina and Brazil more in depth (rather than in a larger number of countries), we can appreciate how two regions handled the opportunities and hurdles provided by the ISI period, and the subsequent trade liberalization and hence how different socio-institutional settings reacted to similar types of policies.

This will allow us to establish a clearer link between the evolutionary and the LAS literatures in order to explain how structural change dynamics occur.

Our approach to explore structural change is threefold.

The first targets the *direction* of structural change which is meant as the shift of industrial production towards more R&D-intensive sectors, the engine not only of the manufacturing sector, but also of the whole economy.

The second examines the *dynamics* of structural change through a productivity decomposition *formula* which allows explaining the aggregate outcomes of productivity by the quantification of structural change.

The third definition of structural change refers to the evolution of *productivity dispersion* across similar manufacturing sectors in order to grasp their degree of capital and technological penetration.

A number of reasons justify the focus on the *manufacturing sector*. Among the predominant ones is the strong link between industrial development and catch-up in relation to the rest of the world: in LA, efforts towards economic growth translated into development policies targeting precisely the industrial sector (Cimoli *et al*., 2014).

A second reason is the importance of the industrial sector as the focus of learning as well as generation, accumulation and diffusion of technological knowledge to the entire economic system. The rising share of technology-intensive activities in manufacturing can be a good proxy for the learning process of the whole economy (Cimoli *et al.*, 2014:81).

The third motivation is linked to data availability. Data on the industrial sector for Argentina and Brazil are readily accessible and boast an extended time series (38 years, from 1970 to 2007) which is key to studies on structural change.[6]

The fourth reason is the sector's relative importance within their national economy. The industry represents a considerable part of the production system as observed from its foundation through to its thriving. In fact, despite the fact that, from the late 1980s, the service sector has gained weight when compared to the industrial one, the new practices of reshoring, offshoring and industry 4.0 have provided the industrial sector with a renewed prominence. Nowadays the industrial production continues being the commanding heights of technological generation and diffusion (see Brettel, *et al.*, 2014).

The fifth motivation lies in the divergent economic reforms endeavoured in both countries. In fact, on the one hand from the 1970s through to the 1990s, the industrial sector was the main target of both Import Substitution Industrialization (ISI) (approximately from the 1960s to the 1970s) and, on the other hand, trade liberalization policies (during the 1990s) (Cornia, 2014). By placing the role of the state at the centre of the strategy (a *tout-curt* state-led industrialization) ISI aimed to include more mechanization in agriculture and in other industries. Conversely, trade liberalization policies and measures gave rise to a new and opposing development paradigm that placed global markets at the centre of policy agenda. The sharp contrast of the two reforms targeting the industrial sector reveals the saliency of the conclusions to draw from this study.

Finally, Brazil's and Argentina's manufacturing sectors were selected as the main case studies of this research since their economic development has been recurrently threatened by a major issue that is to date particularly worrying

[6] The risk is that identifying changes in a small period can be utterly misleading. Take for example the case of Argentina's financial default in 2001. In correspondence of this year and the two years after economic figures such as exports, wages, and productivity are characterized by the most negative peak ever reached in the country. Identifying a structural change in this period can be misleading as it is not easy to isolate say the productivity change from the financial turbulence experienced in those years. In this regard Marchal (1955) argued that:

> "…But if these structural effects are discovered and utilized in the short-term analysis they are not explained therein. It is therefore the role of long-term analysis to appraise not only the consequences, but also the causes of structural tensions. In a long period structural changes become themselves perceptible for the economic subject." (Marchal, 1955:1).

and yet unresolved: the pronounced specialization in low dynamic sectors typically bound to natural resources intensive industries leading to major shifts in their sectoral performance over time. Both countries can be considered as text-book examples of the so-called “Dutch disease”. Their heavy reliance on natural resources, of which they are richly endowed shifts factors of production away from the more dynamic, R&D and technological intensive sectors.

The following research questions will illustrate how structural change will be examined:

1) What is the direction of structural change?

2) How can structural change be quantified?

3) How can these results be read in terms of the industrial policies and reforms implemented during the period 1970-2007? Can significant differences be identified between the two countries’ patterns of economic development?

To answer these questions we will use panel data on Argentina and Brazil spanning 38 years (1970 to 2007). The data collected by the Economic Commission for Latin America and the Caribbean (ECLAC) is called Analysis Program of Industrial Dynamics (PADI, Katz and Stumpo, 2001). A key feature of PADI is the possibility of grouping the 28 manufacturing industries into three main “macro-sectors”, according to their main factor of production, namely: labour intensive (LI), natural resources (NR) and R&D intensive industries.[7] Such division is crucial as it enables the understanding of the direction of structural change (e.g. towards R&D rather than NR intensive sectors).

Our results show that there are remarkable differences in the patterns of structural change between the two countries and that such differences account for their divergent growth performances. In particular, while Brazil showed an R&D driven structural change, in Argentina this role is played by NR intensive industries. In the latter case this indicates a low dynamism in the change of the composition of the production structure. Furthermore, for both countries the main factor responsible for productivity growth is the “within component” of the productivity decomposition, that is the one related to the internal industrial dynamics. However the contribution of structural change (represented by the “between component”) is much more pronounced in

[7] Here the term “macro-sector” is the same as the concept of “sector” in the paper of Cimoli *et al* (2006:31). However, in the current work term “sector” and “industry” are used interchangeably in order to indicate the 28 sectors composing the whole manufacture of the country.

Brazil than in Argentina. More specifically in the former country structural change is driven by R&D sectors, whereas in the latter it is propelled by natural resources intensive industries, a factor exacerbating the Argentinian secular specialization in NR.

This paper is structured as follows. In section 2.2. we review the relevant literature to explain the theoretical foundations of structural change. Section 2.3. illustrates the data that we use. Section 2.4. proceeds with the description of the empirical strategy measuring structural change. Section 2.5. presents the hypothesis, while section 2.6 illustrates the results and their discussion. Finally section 2.7. concludes by explaining and comparing the patterns of productivity dynamics with an historical perspective. This will serve as a platform for understanding how and to what extent policy tools actually affected patterns of industrial development so as to be able to draw some key lessons for their future industrial and economic growth.

2.2. Literature review

2.2.1. Theoretical approaches. Structural change dynamics: Latin American Structuralism (LAS) and its link with the Schumpeterian literature

The theoretical framework to examine structural change dynamics adopted in this work embraces two main strands of literature: the Latin American Structuralism (LAS) and the Schumpeterian literature. Both approaches pay particular attention to the "sectoral" nature of economic development and in particular to the ability of shifting the productive resources from primary to more dynamic sectors, typically characterized by R&D and technology intensive industries. A changing specialization should exert a positive impact on employment, demand and, ultimately, generate more productive and better-quality jobs (Cimoli *et al.*, 2014). These adjustment processes should be envisaged as the direct outcome of the ever rapidly evolving demand of consumption, capital, international competition and technological change.

LAS originated around the 1950s and has to be mainly credited to the pioneering work of Prebisch (1950) and his conception of economic development. Prebisch (*ibid*) believed that underdevelopment needs be analysed within a specific historical context, hence it requires its own theorizing. He regarded the international economy as inherently asymmetrical. The widely used setting was a dual model made up by "the centre" (or developed economy) and "the periphery" (or underdeveloped economy). This latter framework is well suited to describe the economic structure of Argentina and Brazil.

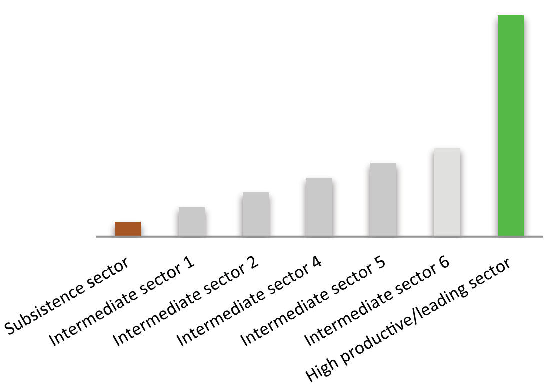
On the one hand, the centre economies (made up by highly productive or leading sectors) tend to be specialized in industrial production and are thus much more complex and diversified, wherein the access to technical change is eased by their well-developed industrial activities, supported by a high degree of monopoly power (Cimoli and Porcile, 2011) (see Graph 2. 1).

On the other hand, the production structure of the periphery (made up by the subsistence sector) is pre-eminently oriented towards agricultural and primary products wherein a shortage of savings and a low rate of capital formation, along with a tendency of high inflation and long-lasting high unemployment, are conducive to a lower standard of living (Jamenson, 1985). Prebisch's (1950) idea of a "dual economy" disregards the notions of economies as homogeneous, similar and harmonic entities, and rather conceives them as structured, heterogeneous and mixed ones (Prebisch, 1950, and Furtado, 1961). This directly reflects the anthropological - and original - definition of structuralism by Strauss (1955) stressing that each system must be studied as an organized set that comprehends its constituent and inter-related elements, rather than by breaking down such system into individual components separately considered. Hence any analysis requires to be historically and context contingent.

Neo-structuralism represents a natural and more recent continuation of the LAS approach that emerged in order to analyse the recessive period of the 1980s experienced by the region, the so-called 'lost decade'. By disregarding the notion of markets as self-regulating systems ending up in equilibrium, neo-structuralism stresses the importance of enduring technological asymmetries and structural heterogeneity as the core elements causing a delay in the industrialization process of the periphery (Cimoli and Porcile, 2011, 2010a and 2010b).

Graph 2. 1

Dual economy and needs for production diversification



This low production diversification, which is the central focus of both LAS and neo-LAS, can be understood as the result of the unequal capital and technological penetration. Such mono-specialization in turn feeds the vicious circle of poor growth, underemployment and poor income distribution.

In this context structural change can be envisaged as the process through which investments are geared towards the generation of intermediate (between the subsistence and the frontier sector, the grey bars in Graph 2. 1) and higher productive sectors which tend to be more dynamic in the Schumpeterian and Keynesian sense (Cimoli, 1988; Cimoli and Porcile 2011; and McMillan and Rodrik, 2011).[8] In fact, these sectors should boost rates of demand growth, as well as more opportunities for technical change. Industrialization can be seen as a process by which developing countries can find a way out from their "peripheral" condition.

Such technological asymmetry can be narrowed down through a shift of resources towards more R&D intensive sectors, whose growth can be seen as strategic for three main reasons. First, because high-technology sectors appear to yield a higher added value per unit of production (Katz, 2001, and Cimoli, 2007); second, because they are likely to generate inter- and intra-industry linkages and spill-overs through endogenously created capabilities (Von Tunzelmann, 2010); and third, because they facilitate the catching up process, measured by the extent to which the production specialization of a country closes the gap with those countries at the technological frontier (Pasinetti, 1981).

LAS and its continuation, neo-structuralism, are deeply intertwined with the Schumpeterian literature, though in the latter the link between development and innovation is made more explicit. Schumpeter (1942) coined the term "creative destruction" which resembles the disruptive effect of the technological progress on older technologies and/or ways of production. By this, Schumpeter referred to an economy not as one in a static equilibrium, but rather as one that is continuously being disrupted by technological improvements. The turbulent process of industrial evolution strictly depends on the market forces, that in turns justifies our focus on output (which can be taken as a proxy of market share) and productivity in the productivity decomposition formula (see section 2.4.2.). If market forces work towards the

[8] The economic structure of a country is a key determinant of its level of income and wages. For example OECD found that Germany and the United Kingdom are positively influenced by their prevailing economic structure which focuses on high-productivity industries, such as manufacturing and financial services. Conversely they found that Japan and Korea's productivity are negatively affected by their economic structure centred on low productivity sectors such as agriculture and construction (OECD, 2002).

right direction, the sectors with above-average productivity levels are likely to thrive, while sectors with below-average productivity levels are likely to shrink, which well reflects the creative destruction process described by Schumpeter (1942). This work combines and blends both the Schumpeterian and the LAS literature/theoretical approaches.

2.2.2. Relevant empirical contribution for measuring structural change

The main goal of this paper is to study the *direction* and *dynamics* of structural change by building upon the theoretical strands and by extending and combining two well-known empirical works addressing the topic of structural change: Holland and Porcile (2005) and Cantner and Krüger (2008). The theoretical and empirical link shared by both works is based on the idea that productivity growth can be achieved *via* two ways: the first way is within its economic sectors, due to capital accumulation, technological change, etc.; the second one occurs *across* sectors, with resources shifting from low to high productivity industries (McMillan and Rodrik, 2011).

Holland and Porcile (2005)[9] examine structural change embedded in the Latin American context by implementing a shift-share analysis decomposing aggregate labour productivity growth - focusing on productivity and employment as main variables of interest - for six Latin American countries into three components. The first component measures productivity growth within each industry; the second focuses on the effect of labour moving from industries with low labour productivity to those with high labour productivity; and the third evaluates the effect of labour moving from industries with low labour productivity growth to those with high labour productivity growth. Their findings reveal that during the period 1970-2002 the productivity growth in the manufacturing sector was mainly due to the within component. Conversely, the between sector component, which represents labour reallocation from sectors with low labour productivity to sectors with high productivity, does not significantly contribute towards the overall productivity growth. This is symptomatic of an economy that is not capable of changing resource allocation across industries, which is one of the main drivers of economic growth. Their work is crucial in order to confront and corroborate

[9] The calculation of the productivity decomposition draws from Fagerberg (2000) and it is expressed as follows: $\frac{\Delta P}{P_0} = \Sigma\, [\frac{P_{i0} \Delta S_i}{P_0} + \frac{\Delta P_i\, \Delta S_i}{P_0} + \frac{S_{i0}\, \Delta P_i}{P_0}]$, where P_i is the labour productivity within industry *i*, S_i is the participation of the industry in the total of employment, Δ is the variation fo a given variable between the period t and t-1.

our results since we will use a variation of the productivity decomposition *formula (*there called "shift share analysis")*.* This brings us to the second empirical work that serves as a backbone of the current analysis, which is briefly described below.[10]

Cantner and Krüger (2008) serve as the empirical reference for this paper. Similarly to the above-mentioned work, this paper also explains aggregate productivity changes (focusing on productivity and output) through a shift-share analysis (here called "productivity decomposition *formula*"). They use productivity data on German manufacturing firms divided into 11 different industries at roughly two-digit level over the period 1981-1998 and they analyse both firms and sector dynamics in Germany. Through the productivity decomposition they found that the contribution of structural change (or the between component) and the net entry of firms are the two main candidates in explaining aggregate productivity growth, especially after the German reunification. They argue that this finding is consistent with the success-breeds-success dynamic hypothesis, coupling economic and technological development, wherein above-average productivity firms are selected in favour of below-average productivity ones (the so-called replicator dynamics). Conversely, within firm productivity growth accounts for much of the performance especially in the period before reunification (for the formula specification refer to section 2.4.2).

2.3. Data

The analysis is based on the PADI covering 28 manufacturing sectors from 1970 to 2007 classified according to the International Standard Industrial Classification (ISIC rev. 3) for Argentina and Brazil (PADI, Katz and Stumpo, 2001). The 28 industries can be categorized[11] into three main macro-sectors according to the most used factors of production, namely:

- NR intensive industries: 13 sectors;
- LI intensive industries: 10 sectors; and
- R&D intensive industries: 5 sectors.

The sub-specification of each macro-sector is shown in Table 2. 1. Due to their specific characteristics, the R&D intensive industries can be considered the

[10] Other relevant empirical contribution dealing with shift-share analysis and structural change we took as a reference include: Timmer and Szirmai (2000), Wang and Szirmai (2008) and van Ark and Timmer (2008).

[11] For the classification refer to Cimoli *et al*., 2006.

most technologically intensive (Cimoli, *et al*., 2006 and Katz, 2001). Such macro-sectoral division is crucial since it enables understanding the direction, mechanism and dispersion of productivity growth and structural change with a sectoral perspective. The database offers aggregated data at constant prices (1985 as base year) for a number of variables, among which those that will be used in the current work are:

- employment (number of people);
- gross output (the sum of the value of goods produced in the country, including the value of intermediate goods used in the production, million US$, constant prices);
- value added (given by the gross output minus the value of inputs, million US$, constant prices); and
- productivity (output produced per unit of labour input US$, constant prices).

Table 2. 1

PADI: sectors' classification NR, LI and R&D intensive industries (macro-sectors)

(3-digit ISIC sectors classification Cimoli *et al*.2006)

ISIC	Macro-sector	Industrial sector	ISIC	Macro-sector	Industrial sector
311	NR	1) Food	341	NR	15) Paper and paper products
321	LI	2) Textiles	351	NR	16) Industrial chemicals
322	LI	3) Clothing	353	NR	17) Petroleum refineries
323	LI	4) Leather and leather products	354	NR	18) Coal products
324	LI	5) Footwear	355	NR	19) Rubber products
332	LI	6) Furniture	362	NR	20) Glass and glass products
342	LI	7) Printing and publishing	369	NR	21) Non-metallic mineral products
352	LI	8) Other chemical products	371	NR	22) Iron and steel
356	LI	9) Plastic products	372	NR	23) Non-ferrous metals
361	LI	10) Pottery	381	R&D	24) Metal products
390	LI	11) Other manufacturing industries	382	R&D	25) Machinery except electrical
313	NR	12) Beverages	383	R&D	26) Electrical machinery
314	NR	13) Tobacco	384	R&D	27) Transport equipment
331	NR	14) Wood and wood products	385	R&D	28) Professional and scientific equipment

Source: own elaboration on the base of PADI - UN, ECLAC.

2.4. Empirical strategy for measuring structural change

The first aim of this work is to examine the *direction* of structural change by observing the industrial evolution of macro-sectoral specialization.

Secondly, we unravel the *dynamics* driving productivity growth through the productivity decomposition *formula*.

Thirdly we explore the degree of productivity heterogeneity (or productivity dispersion) within each of the macro-sectors to unravel whether industrial sectors are characterized by persistent asymmetries in their productivity level.

Section 2.6. will present and discuss the results through an in-depth analysis of the calculated coefficients along with the growth rates of our variables of interests, which are shown in Appendix A.

2.4.1. The direction of structural change: value added by macro-sector

The diversification of production structure, that is the shifting from largely natural resources (of which the region is abundantly, though in the long term exhaustedly, endowed) to R&D intensive industries represents one essential step towards structural change (Katz, 2001). There is a bulk of empirical evidence showing that a shift in the composition of the production towards R&D intensive industries enables the achievement of higher growth rates in the long term, while increasing a country's capacity to respond readily to demand changes and reducing the technological gap with respect to the technological frontier (Cimoli *et al*., 2006, and Katz, 2001:52)

This section seeks to provide a measure to understand the *direction* of change (*ibid*). Given the possibility of grouping all the 28 manufacturing sectors into three main macro-sectors – NR-, LI- and R&D-intensive industries - structural change, depicted as the production structure's dynamism, can be expressed simply as the share of value added of R&D intensive industries in the total manufacturing added value over time:

$$Sva_{it} = \frac{va_{it}}{\sum_i^n va_{it}}$$

where i is the sector and t is the year taken into consideration summed up by macro-sector. The measure above allows understanding to what extent a macro-sector gains relative participation in value added with respect to the overall manufacturing industry, thereby defining the change in the region's pattern of specialization.

2.4.2. The dynamics of structural change

An original contribution towards the measurement of structural change comes from Cantner and Krüger's (2008) productivity decomposition based on output and productivity as the main variables of interest. In line with evolutionary theory, they develop a *formula* decomposing the productivity, both on aggregate and individual firms, showing how and to which extent structural change can be explained by productivity growth dynamics (*ibid*: 124).[12] Their work focuses on firms whereas our study specifically addresses the *sectoral* dimension as unit of analysis.

Below we present the specifications of the productivity change *formula* applied and extended to our data:

1) Share of output. Let s_{it} and s_{it-k} denote the ratio of output of sector i over the total output at time t and $t-k$ respectively. The change of output share, which we use as a proxy for market share of a specific industry, at time t minus relative share of relative output at time $t-k$ would be equal to $\Delta s_{it} = s_{it} - s_{it-k}$;

2) Productivity. Let a_t^s and a_{t-k}^s indicate average productivity (measured as output over employment) at time t and $t-k$, respectively. The change of average productivity is the difference between the productivity at time t and the productivity at time $t-k$, $\Delta a_{it} = a_{it} - a_{it-k}$; and

3) Share weighted average productivity. $\bar{a}_t^s$ is the result of the productivity multiplied by the share of output and summed up for all industries n in the year t.The change in the average productivity between year $t-k$ and year t, $\Delta\bar{a}_t^s$, is the difference between the respective years' average productivities: $\Delta\bar{a}_t^s = \bar{a}_t^s - \bar{a}_{t-k}^s$.

The average productivity change (in percentage) can be decomposed into three terms

$$\frac{\Delta\bar{a}_t^s}{\bar{a}_t^s} = \frac{\sum_i(s_{it-k}\Delta a_{it})}{\bar{a}_{t-k}^s} + \frac{\sum_i[\Delta s_{it}\,(a_{it-k} - \bar{a}_{t-k}^s)]}{\bar{a}_{t-k}^s} + \frac{\sum_i(\Delta s_{it}\,\Delta a_{it})}{\bar{a}_{t-k}^s}$$

[12] Cantner and Krüger's (2008) results are similar both at a firm and sectoral level (firms are sampled together at 2-digit Standard Industrial Classification (SIC)). This allows us to safely apply the productivity decomposition formula to PADI's industrial sectors (ISIC.rev. 3).

The first term indicates the within productivity component and multiplies the variation in productivity from $t-k$ to t with the output at a sectoral level at time $t-k$. Therefore if the output is positive, but the variation in productivity is negative then the within component is negative.

The second term reveals the between sectors component of productivity growth. If the sector has a positive variation in output ($\Delta s_{it} > 0$ is) but its productivity is below the average productivity of all the sectors ($a_{it-k} - \bar{a}^{s}_{t-k} < 0$) then the term is negative. This term shows whether the industries (or sectors) are growing virtuously or not compared to the average productivity performance of the other sectors. This happens only when the term is positive and hence when the variation in output and the difference between that sector productivity and the average is either a '+ +' or '- -'. Let's take the '- -'. In this case we would have a sector that is losing in output from one period to the other and a productivity that is inferior to the average productivity of all industries. Therefore the sector which produces less but also in a less productive way than the average, will result in a positive-sign of the between component. The selection of sectors is working towards the right direction since sectors that are less productive than the average are also losing share of output.

The third term, the covariance component, multiplies the variation in output with the variation in productivity and describes the acceleration with which the productivity growth takes place.

All terms of this sum are divided by the share-weighted average productivity of year $t-k.$

We perform this calculation taking, first, all the 28 sectors into consideration, and, second, focusing on the aggregated macro-sectors.

The main differences between Cantner and Krueger's (2008) and Holland and Porcile's (2005) approaches are related to different units of observation and a different conceptualization of productivity growth. While the latter work addresses the effect of employment moving from low to high productivity sectors, the former analyses structural change by considering productivity and output (used as a proxy of market share) accounting in a more detailed manner for inter-sectoral differences in production performance over time.

2.4.3. Productivity or structural heterogeneity

The degree of inter-sectoral productivity heterogeneity is essential to examining whether industrial sectors are characterized by persistent asymmetries with a polarized productivity structure, a common feature in developing countries that tend to specialize in the production of low-tech goods.

Many studies confirm the high level of productivity polarization or structural heterogeneity characterizing Latin America (see Pinto, 1970 and 1976; Holland Poricile, 2005; Infante, 2011; and Infante and Sunkel, 2009 among others). By re-proposing the methodology adopted by Holland and Porcile (2005) in this section we calculate the relative variance of the level of productivity and applied at a macro-sectoral level. This will allow understanding whether there are persistent asymmetries within each macro-sector and whether these tend to change over time. [13]

2.5. Hypothesis

Despite many commonalities in terms of policies and reforms, we expect to find in Argentina and Brazil two contrasting case studies which justify our concern to interpret the results with an historical perspective. Such perspective is vital to understand the reason why similar policies affected countries in a divergent manner. From the descriptive statistics (see Table A.2.1., Appendix A) it is possible to observe that Brazil boasts the highest share of output in all macro-sectors, an indication of a higher economic potential as compared to the Argentine case (especially in the R&D macro-sector). Given this strong dynamism we hypothesize:

H1: R&D value added should be higher in Brazil than in Argentina.

H2: Structural change, or the between component of the productivity decomposition, should be more pronounced in the former than the latter country. Additionally we expect that the between component takes on the highest values within R&D industries in Brazil and in NR industries in Argentina.

H3: With respect to the time period, we expect an overall higher productivity growth during the ISI period than during trade liberalization. The relevant literature emphasizes the stress under which production plants were put through due to the opening up to imports of the 1990s, especially in Argentina. The least productive firms which lost market shares were forced to shut down, raising the average productivity of those remaining in the market.

[13] An additional tool to grasp the level of productivity heterogeneity comes from the descriptive statistics (see tables A.1.1-3. for Brazil and tables A.5.1-3. for Argentina in Appendix A) and especially from the between variation of productivity which describes the variation of productivity of sectors within each of the three macro-sector over time.

For this reason productivity growth was spurious (*i.e.* due to a loss in employment rather than an actual increase in output) (Frenkel and Rapetti, 2011).

H4: with respect to productivity dispersion we expect to find in both countries a higher variation of productivity levels within NR intensive industries, where highly differentiated sectors coexist (*i.e.* the high capital intensive ones like oil and coal and those less capital intensive like wood and wood products) than in R&D industries since supposedly they are characterized by a more uniform technological and capital penetration.

2.5.1. Historical context: industrial reforms in Brazil and Argentina

Before presenting our results, we offer a brief summary with the key points describing the historical context featuring the two countries (for a more in depth review refer to the introductory *Chapter 1*, section 1.5).

Both countries experienced similar industrial policies and crises[14], namely:

- The ISI period took off around the 1950s until the end of the 1970s and it was featured by a remarkable State participation in the economy, largely financed through foreign debt, subsidies and tariff barriers (Bielschowsky, 2010). Imports were substituted by domestic production, which strengthened remarkably. In this context the manufacturing sector was relatively potected from external competition reducing the technological gap with the frontier (Cimoli *et al.*, 2014).[15]
- The debt crisis of the 1980s led to a period of recession that lasted until about the beginning of the 1990s. This period revealed the unsustainability of the previously chosen model, to finance economic development with external savings (*ibid*).
- The 1990s witnessed the implementation of a set of neoliberal policies that were opposite in their nature to those of ISI. Such policies aimed at promoting deregulation, privatization, open trade and liberalization of the financial flows, whereby the role of the State was largely downplayed by free market dynamics. The paradox is that during the

[14] In Boxes 1.1. and 1.2. in the introductory chapter, we present the subdivision of the economic/political periods for both countries that will serve as the backbone to calculate and interpret our results.

[15] Allegedly, Cimoli and Katz (2003) highlighted the Argentine case, whose automotive industry was internationally considered as an example of excellence in production.

1990s productivity growth for most of LA countries accelerated, while the specialization patterns tended to move towards low-tech industries (*ibid*).

Despite similar reforms experienced by both countries, two major differences deserve special attention. The first is that Brazil has been more committed to industrial development than Argentina, since its ISI endured throughout the 1970s. Conversely, Argentina interrupted ISI in the late 1970s by endeavouring an early attempt of trade liberalization (*ibid*).

The second distinction lies in the different use of the exchange rate policy by the two countries (Novick *et al*., 2007). After the 1990s, Argentina adopted a fixed exchange rate that led to the greatest social and economic crisis in its history in 2001 (Cimoli *et al*., 2014). Conversely, Brazil embraced a band of fluctuation for the nominal exchange rate which provided more freedom to devalue and readily react to external shocks (*ibid*).

2.6. Results and discussion

In order to deepen the discussion on structural change, this section addresses the *direction*, *dynamics* and *distribution* of productivity in the Brazilian and Argentine manufacturing industry from 1970 to 2007.[16]

2.6.1. Direction of structural change

The first building block of our analysis assesses the *direction* of structural change by looking at the composition of the production structure measured by the value added share of each macro-sector over the total value added. Does it tend to be stable over time? Which sectors are responsible in generating a higher value added? But most importantly, are R&D intensive industries gaining share with respect to the other two macro-sectors, thereby triggering the much-advocated structural change?

The most striking result for both Argentina and Brazil is the high value added of NR intensive industries, as opposed to the much lower values of LI and R&D ones, throughout the whole period (see Graphs 2.2. and 2.3.). Despite this, in Argentina, starting from the period of the early trade liberalization, the share

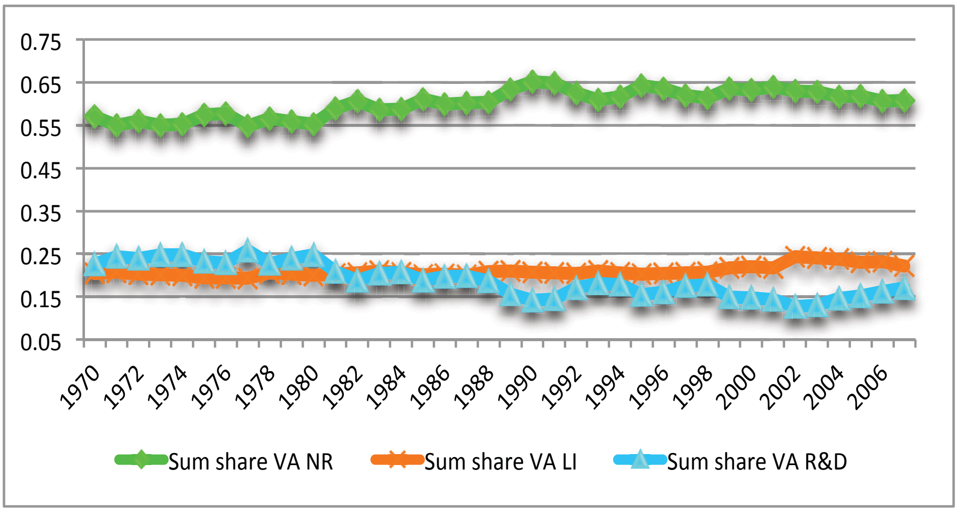
[16] All graphs and tables' sources are the outcome of own elaboration based on the PADI (Katz and Stumpo, 2001) database- UN, ECLAC.

of R&D gradually decreased and became the lowest from the 1980s onwards (Graph 2. 3.). Conversely, in Brazil R&D intensive industries' value added has outperformed the LI one, starting from the 1970s - during the ISI period - and its value has almost converged to the one of NR industries at the end of the period.

If we look at the Argentine situation more closely (Graph 2. 2. and Table A.6.1. in the Appendix A) we can see that only during the early 1970s did the country seem to be in a position to embark on a path of production diversification, whereby the R&D industries value added grew on average by 3.5% (whereas the growth in R&D value added was always negative in the remaining period). This success must be credited, at least partly, to the protectionist measures of the ISI that kept the manufacturing sector relatively sheltered from external competition and therefore allowed a higher industrial diversification which was accompanied by strong social integration (Cimoli *et al*., 2014), along with an overall employment growth of 20%.

Graph 2. 2.

Value added by macro-sector, Argentina



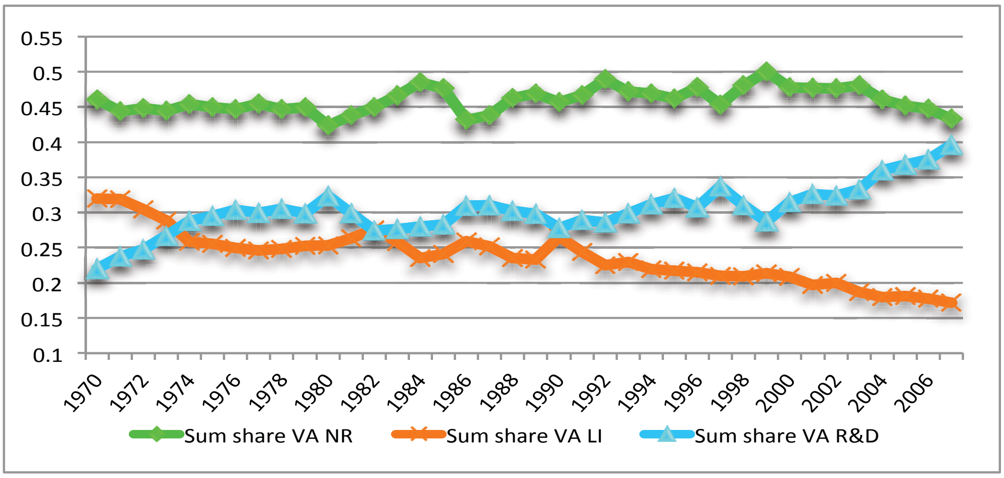
However, the imposition of a military dictatorship that carried out an early experiment of trade liberalization undermined this process, leading to a progressive reduction of R&D intensive industries value added whose share dropped to 24% of the total value added in 2002. NR industries value added growth was the highest throughout almost all the periods which is indicative of an essentially natural-resource centred industrialization process, a factor that constitutes one of the major concerns of the low diversification of the

Argentine production structure. From a structuralist perspective such a low degree of heterogeneity does not ease, but rather hinders the processes of structural change.

Brazil, similarly to the Argentine case, is characterized by the predominance of NR intensive industries (Graph 2. 3.) that make up the lion share: on average they represent 45% of the total value added. Nevertheless, in the Brazilian case, the R&D value added experienced the most dramatic increase: starting from the early 1970s it gradually caught up, and in 2007 it almost converged with that of NR intensive industries. R&D sectors accounted for 21% of the share of the total value added in 1970, and reached 40% in 2007. This R&D evolution can be, at least partially, credited to the success of ISI policies wherein Brazil set industrialization and production diversification as the main priority (*via* the First National Development Plan, I PND, 1968–1973 and the Second National Development Plan, II PND, 1974–1979) (Cimoli *et al.*, 2014). During the 1970s the country made extensive use of ISI and subsidies for industrial exports also thanks to the active role of its biggest local development bank (BNDES) (Ocampo and Ros, 2011).

Graph 2. 3.

Value added by macro-sector, Brazil



Overall, in both countries the market-oriented reforms of trade liberalization starting in the 1990s were meant to provide a dynamic shift in the production structure towards one of the region's main comparative advantage, namely unskilled labour. This did not occur in Brazil or Argentina (nor in the remaining southern corn countries) (Katz, 2001). Overall industrial production has intensely specialized in NR, hence in favour of static comparative advantage which tends to be highly capital intensive, computer-based and low-employment absorbing. This specialization bias towards NR precisely represents the so-called “primarization” of production, one of the major concerns of both economies which in fact need to reverse this trend by shifting resources towards labour- or skill-intensive sectors (typically R&D intensive industries).

A further common observation is that the LI macro-sector lost ground, though with a greater extent in Brazil, due to the competition from the low-wage East Asian countries (*i.e.* China, Vietnam etc.). In fact, the growth rate of the Brazilian LI industries’ value added was negative throughout all the periods, a development which did not occur in Argentina (Table A.2.1. for Brazil and A.6.1. for Argentina in Appendix A). For instance, during trade liberalization Brazil LI industries’ value added decreased by 13% while in Argentina it grew by 5.7%.

Nevertheless, in Brazil, despite the predominance of NR industries value added, the gradual growth of R&D intensive sectors is indicative of a relatively more dynamic industrial development which has the potential of reducing the dualistic structure of the economy while pursuing the much needed structural change.

2.6.2. Dynamics behind structural change: productivity decomposition with output and employment

By focusing on output (which we use as a proxy for market share) and productivity, this section describes the *dynamics* of structural change through the productivity decomposition *formula* (Cantner and Krüger, 2008). We will demonstrate that there are considerable differences in the patterns of structural change across the two countries as well as macro-sectors. A closer look into the data reveals that in Brazil, contrary to the Argentine case, not only value added, but also the degree of structural change is defined R&D and technological intensive sectors.

Tables 2.2. and 2.3. illustrate the productivity decomposition resulting from the application of the Cantner and Krüger’s (2008) *formula* and over all industries for the two countries.

Both in Brazil and Argentina productivity growth is primarily due to the within component and so it is related to industries internal dynamics rather than a thoroughly structural change which is in line with the findings of Holland and Porcile (2005). In Brazil this term is highly positive during the ISI (1970-1980) and trade liberalization (1994-2003). The between component, which is the indicator of structural change, is positive only during the ISI and lost decade period but much smaller in magnitude.

Likewise in Argentina productivity growth is mainly driven by industries' internal dynamics wherein the within component is positive during all periods with exception of the ISI. The between component of structural change is positive only during the first period of early trade liberalization and during the lost decade.

When a positive within productivity component is accompanied by a positive between productivity component (green square in Tables 2.2. and 2.3.), it is indicative of a productivity growth supported by structural change, whereby industries with productivity above the average are gaining market share (or output) (or industries with below market productivity are concomitantly losing market share). This type of growth is consistent with productivity enhancing structural change.

This was the case of Brazil during the ISI period that provided a sheltered environment in which firms were experiencing a positive productivity growth that went along with structural change. Industrialization was conceived as the engine for economic growth and the strong state intervention exerted an overall positive effect on the economy. A similar trend was observable in Argentina during the periods 1976-1981 (early trade liberalization) and 1982-1990 (lost decade).

Conversely, during the period of trade liberalization of the 1990s, the strongly positive within component of both countries was not supported by a positive between component. The contribution of structural change turned negative. This means that even if productivity was overall growing (positive within component) the degree of market selection was not working in the right direction since firms with productivity below the average were gaining output shares (or else, firms with productivity above the average were losing output shares). This is symptomatic of an economy that is actually not capable of changing resource allocation across sectors in an efficient manner, which is one of the main drivers of economic growth. This result is corroborated by the literature maintaining that the period of trade liberalization was featured by the so-called "spurious growth" (Prebisch, 1950).

Table 2. 2.

Productivity decomposition over all industries Argentina					
Summation terms	**1970-1975**	**1976-1981**	**1982-1990**	**1991-2001**	**2002-2007**
Within	-1.818	4.082	0.255	4.402	2.681
Between	-0.923	0.998	0.692	-0.004	-0.022
Covariance	0.382	0.820	0.544	0.591	0.761

Table 2. 3.

Productivity decomposition over all industries Brazil				
Summation terms	**1970-1980**	**1981-1993**	**1994-2003**	**2004-2007**
Within	4.63	-2.12	7.40	-1.61
Between	0.62	0.31	-0.15	-0.34
Covariance	0.56	0.47	0.62	0.41

The opening to imports of the 1990s induced the least productive firms to lose market shares or to shut down, leading to a rising productivity of those staying in the market (which translated to a positive within component) (Pavcnik, 2000, and Ferreira and Rossi, 2003). Hence productivity growth was mainly related to an expulsion of labour rather than an increase in output. This is the so called "industry rationalization": the least productive firms exit the industry, and remaining firms reduce the "excess labour". This scenario precisely depicts the Argentine case, that lost on average 20% of its employment during the second round of trade liberalization (while during the first round of trade liberalization the loss of employment was even higher and reached 33%, see table A.6.1. in the Appendix A).

A first remarkable difference between the two countries is that Brazil did not experience such a dramatic employment expulsion, but rather an increase (on average by 5.4%). These findings suggest that in Brazil defensive rationalization did not hit employment as strongly as in Argentina, and it affected only the value added, productivity and employment of LI industries, while the remaining macro-sectors were growing remarkably (see Table A.2.1. in the Appendix A).

A second significant dissimilarity is that the ISI period was rather more structural change-enhancing in Brazil than in Argentina, which can be credited to the higher commitment that Brazil manifested towards industrial policies as opposed to Argentina, who interrupted ISI - and all the instruments of industrial development it brought about -in 1976 (as seen in section 2.5.1.).

After 2002, the period of commodity-boom manifested through the re-specialization in NR, accounted for soaring global demand of these goods. Both in Argentina and Brazil this factor led to a reduction of structural change (the between component is negative).

2.6.3. Productivity decomposition: comparison by macro-sectors

We can gain further insight into our results by looking at the application of the productivity decomposition *formula* at a macro-sectoral level. Which are the macro-sectors responsible for this overall trend?

Graphs 2.4. and 2.5. indicate that for Brazil the within component takes on the highest value in NR intensive industries. Nevertheless, R&D intensive industries boast the highest level of the between component throughout the whole period (with the only exception of the ISI). We have seen from the theory that the between component is responsible for triggering structural change. Hence in Brazil the increasing importance of R&D intensive industries is twofold. On the one hand, R&D value added is progressively converging to that of NR intensive industries which is key in fostering the change in the composition of the industrial structure towards more knowledge intensive sectors (as seen in paragraph 2.6.1.). On the other hand, the R&D sectors are concomitantly responsible for a more dynamic reallocation of resources whereby sectors with higher productivity than the average are gaining market share (represented by a positive between-component). Thus, a key message emerging from this analysis is that in Brazil, R&D industries have potential both in reducing the dualistic nature of their industrial structure (since the R&D value added is growing constantly over time), and to generate a positive structural change (since the between-component reaches the highest positive values in this group of industries). Looking closely within R&D macro-sector, it is possible to observe that the industries driving structural change (or those with the highest between-component) are machinery except electrical, electrical machinery and transport and equipment.

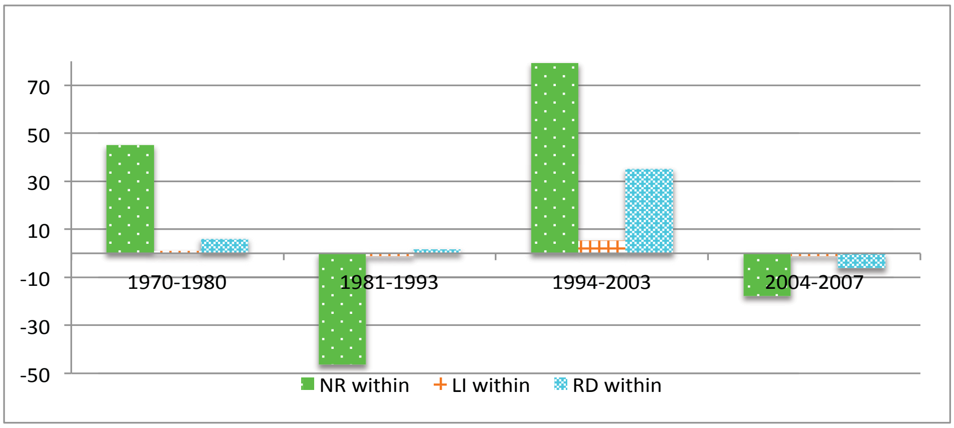
Interestingly, during trade liberalization of the 1990s, NR intensive industries´ between and within components of productivity growth go in opposite directions. Namely, the within component of productivity change is highly positive whereas the between component is markedly negative. Hence, NR industries within-productivity growth was not supported by a concomitant high level of structural change. Overall, NR industries play a dominant role but of poor quality given their low potential for triggering structural change.

LI intensive industries lost ground throughout the period and display the lowest within productivity component. The between component is very low, too, but positive in all periods, meaning that within the LI macro-sector a discreet level of structural change is actually occurring.

Productivity decomposition: break down by macro-sector

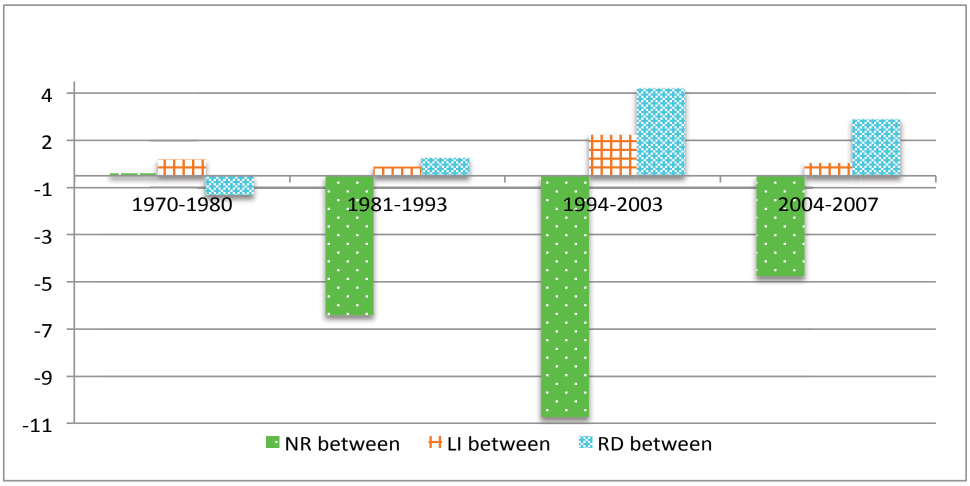
Graph 2.4.

Within component by macro-sector, Brazil



Graph 2.5

Between component by macro-sector, Brazil



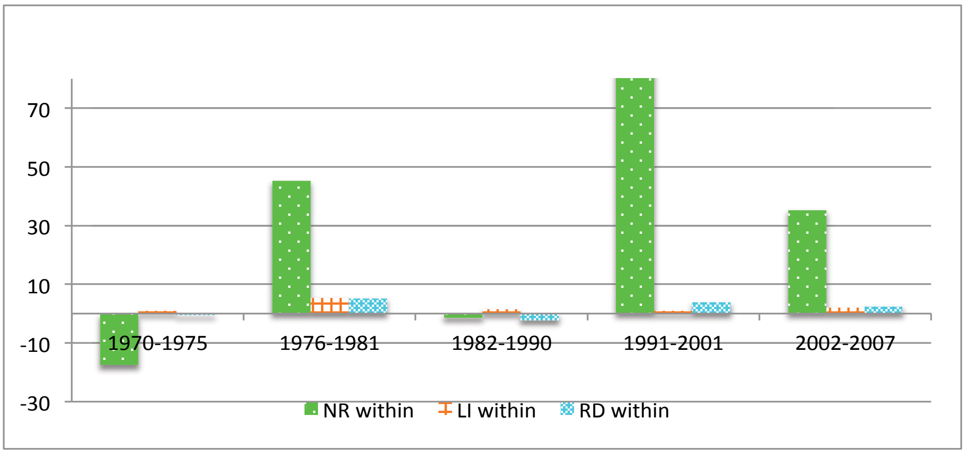
Now we turn to the Argentine case by studying more closely which macro-sector is the driver of structural change. Do R&D industries also have the potential to stimulate structural change as in Brazil? As illustrated by Graphs 2.6. and 2.7. the situation in Argentina appears quite different.

Both the within and the between components take on the highest values in NR intensive industries (with the predominance of the coal and oil sectors). Contrary to what occurred in Brazil, the role of the within and between component of R&D intensive industries is low or negative throughout the whole period. Therefore their role for triggering structural change is negligible. During both periods of trade liberalization the exceptionally high within component of NR industries was not accompanied by a similarly exceptionally high level of structural change, though the value of the between component was positive. In general the between component takes on positive and relatively higher values only in NR industries, implying that in Argentina this is the macro-sector generating structural change (contrary to Brazil where this role was played by the R&D macro-sector). This result brings about important consequences from the structural change perspective. The scope for NR industries to trigger structural change along with their dominance in terms of value added is likely to accrue *ceteris paribus* the low level of structural change of the Argentine economy (the issue of “primarization” of the production structure). Looking closely at the NR macro-sector, the industries that most prominently contributed to structural change were: petroleum and refineries, food and industrial chemicals. The clear specialization in NR industries led to “spurious” productivity growth, which was merely based on favourable terms of trade or exchange rate of the natural commodities being exported (Furtado, 1961 and 1966).

This increasing trajectory of the between-component changed during the following period of the commodity boom (2002-2007), whereby all macro-sectors experienced a negative structural change (or negative between-component) even though the within component was remarkably high, especially in the case of NR industries. This implies that the productivity growth -denoted by a positive within component- was not virtuous since it was not accompanied by a concomitant structural change. Industries that were increasing their output displayed a productivity level below the average of the whole manufacturing sector (or else industries with productivity above the average had a negative output from one period to the other).

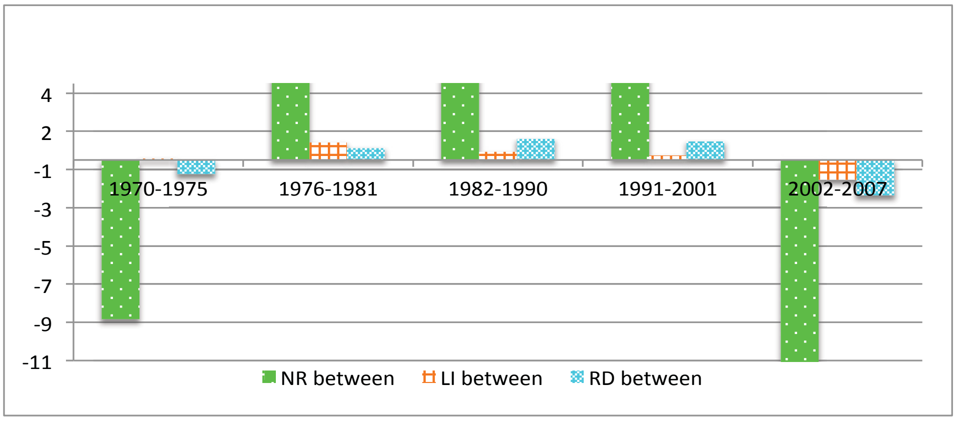
Graph 2.6.

Within component by macro-sector, Argentina



Graph 2.7.

Between component by macro-sector, Argentina



2.6.4. Dispersion of structural productivity or structural heterogeneity

Productivity polarization measured as the productivity variance within a given macro-sector is a good indicator of the asymmetries in the production techniques across sectors. It shows whether sectors that are highly productive thanks to modern techniques coexist with sectors that are not so productive. The indicator illustrates the idea of the dual economy in the structuralist sense, where there is a leading and a backward sector. The high productive heterogeneity can be understood as a direct consequence of the unequal capital and technological penetration.

Tables 2.4. and 2.5. illustrate the relative productivity dispersion calculated within each of the three macro-sectors for both countries in their respective key historical periods.[17] The results, which are very similar for both countries, point to a significant productivity heterogeneity among NR intensive industries. This implies that, within this group of industries, sectors that are highly productive coexist with others that are much less so, which is suggestive of an uneven capital as well as technological penetration. The variance is always above 0.9 for both countries and for all the periods. It seems that in the NR macro-sector the concept of "dual economy" is well represented. In fact, coal and petroleum are the top productivity sectors both for the Argentine and Brazilian case (see Graphs A.3.1., and A.4.1- .4 for Brazil and A.7.1., and A.8.1- .3 for Argentina in Appendix A displaying the productivity evolution aggregated and disaggregated by macro-sector). These sectors coexist with a number of much less productive ones like wood and non-metallic products, the least productive manufacturing sectors. Convergence in productivity levels among NR industries is hardly occurring, nor imaginable as it is often related to the characteristics of the production process in a particular industry (*i.e*. the level of capital intensity is much higher in petroleum than in the wood sector). The scant R&D and technological penetration seems to explain the divergent level of productivity within NR industries. Conversely LI and R&D intensive industries show much less polarized productivity, probably due to their more equal capital and technological diffusion.

Table 2.4.

Measure of variance of productivity, Argentina

Variance in productivity by macro-sector	**1973**	**1979**	**1986**	**1996**	**2005**
NR	0.991	0.989	0.989	0.988	0.949
LI	0.003	0.005	0.006	0.006	0.035
R&D	0.006	0.006	0.005	0.006	0.016

[17] These results are confirmed by the "between" variation in productivity of each macro-sector displayed in the summary statistics in Tables A.1.1. -3 for Brazil and A.5.1.-3. for Argentina in Appendix A.

Table 2.5.

Measure of variance of productivity, Brazil				
Variance in productivity by macro-sector	**1975**	**1985**	**1995**	**2005**
NR	0.998	0.990	0.988	0.991
LI	0.001	0.007	0.004	0.002
R&D	0.001	0.003	0.008	0.007

2.7. Conclusion: different trajectories of structural change

This paper builds on recent research showing that productivity growth is in general mainly due to the within component of the productivity decomposition, especially in developing countries (Holland and Porcile, 2005, and OECD, 2002). As a complement to these studies, we ask how productivity dynamics evolve in two Latin American countries, Argentina and Brazil, paying particular attention to their diverging historical background and production structure. While there are several empirical papers highlighting productivity dynamics and their relationship with catching up, there is little empirical evidence on the implication of such productivity dynamics from a *sectoral* perspective, which we believe is key to studying structural change.

This study unravels the *directions*, *dynamics* and *dispersion* of productivity growth in the Brazilian and Argentine the manufacturing sector from 1970 to 2007. The case at hand is particularly instructive since both countries share common experiences in terms of industrial and trade policies (though with slightly different timing) and external shocks. Yet in Argentina these policies appeared to have had extreme consequences, including a dramatic employment fall during the trade liberalization periods, due to a different economical/institutional setting.

Our findings on productivity dynamics provide several insightful results which for sake of simplicity we divide into two main parts: those related to the economic reforms which are based on the examination of the evolution of the variables of interest; and those more strictly linked to our empirical analysis, underscoring the interplay of productivity dynamics with our main object of interest, namely structural change.

From an historical perspective, industrial and trade policies provided some insightful lessons. In both countries the ISI period boasted the relative catching up of the economy, whereby the presence of R&D intensive industries value added was especially high, together with the highest employment growth of the whole period. However, two distinct models of production in terms of the *direction* of structural change identify the two countries. The first, which is to be found in Argentina, portrays a relatively more pronounced specialization and dynamism in the NR-based sectors. After 1976 with the first attempt of trade liberalization, NR intensive industries remained the most important sectors in terms of value added creation whereas the R&D intensive group progressively lost ground. The second model of production, which belongs to Brazil, despite a predominance of NR-based sectors, shows a gradual but persistent catching up of R&D-based industries value added which, at the end of the period, almost caught up with the one of the NR intensive sectors. The Brazilian R&D value added race to the top appears to foster the diversification of the Brazilian industrial sector. Both countries lost ground in the LI industries with some major downswings in footwear - especially in Brazil - clothing and furniture, as a result of the fierce competition from newly developed Asiatic countries.

In both countries the competitive pressure imposed by trade liberalization reforms of the 1990s boosted the overall productivity, although in Argentina this appears to be spurious. According to Furtado (1961) exceptional cases such as this are mainly driven by a drop in employment (which diminished by 20%), rather than output growth (which dropped by 10%). Conversely, in Brazil, during the same period, the drop in output was comparatively smaller (on average it diminished by -0.3%) and it was accompanied by an increase, rather than a decrease, in employment (on average it raises by 5.4%) (see Table A.2.1. in Appendix A).

Our analytical strategy contributed in providing further insight to the existing literature with a focus on the diverging productivity growth dynamics of the two countries bridging and building upon traditional measures of productivity specialization, growth and heterogeneity.

The productivity decomposition analysis highlighted the *dynamics* behind structural change and helped understanding the different responses of industries to the trade liberalization's reforms. The value added of our work with respect to the existing literature lies in the breaking down of the productivity decomposition *formula* at a macro-sectoral level, which combines the direction of structural change with its inherent mechanisms. As we saw, this aspect is key in determining the divergent performance of productivity growth which, again, sees Brazil in a relatively more favourable position with respect to Argentina.

In the Argentine case the macro-sector responsible for triggering structural change (represented by the between component of the productivity decomposition) is the NR intensive one, throughout most of the period with a major peak during the second round of trade liberalization. This finding highlights that the severe consequences of defensive rationalization strategy in Argentina were twofold. On the one hand in this period the industry suffered from consistent expulsion of employment. On the other hand, this strategy precisely acted in fortifying the Argentinian enduring specialization in NR. The sheer contribution of structural change to the dramatic increase in the within productivity component during the 1990s of NR industries, has been masked by the fact that overall productivity was decreasing (-47.03%) and so did its value added (-1.46%). Nevertheless during this period output grew by 7.8%, which is mirrored by a positive within component. The industries that most significantly contributed to the growth of the within component were: iron and steel, industrial chemicals, non-ferrous metals, food and petroleum and refineries. R&D intensive industries' contribution both to structural change and to the within productivity growth is rather low or negative. As Cimoli *et al*. (2014) rightly argued, structural change tends to respond more slowly to policy changes than productivity and employment. The authors claim that during the period of currency appreciation economic sectors were severely affected by falling competiveness and demand, wherein capabilities and skills were gradually eroded. During the crisis, production and the accumulation of human capabilities were demolished also as a result of the accumulated disequilibria of the previous period (*ibid*).

This scenario is reversed in Brazil, whereby R&D intensive industries were the main drivers of structural change especially during the period of trade liberalization. The period of defensive rationalization imposed by trade liberalization, spurred the country's effort to generate structural change *via* R&D industries (especially thanks to the machinery except electrical, and electrical machinery, sectors). The evidence we found on such structural change certainly accounted for the diversification of the composition of production structure towards relatively more dynamic and knowledge intensive/R&D sectors. If we interpret these results with an historical perspective, it goes without saying that the growth in employment in Brazil is actually a good indicator of thoroughly economic development whereby structural change is occurring thanks to knowledge and R&D intensive sectors without the dramatic expulsion of labour force that instead affected Argentina.

The level of productivity heterogeneity shows similar trajectories for both countries, with NR intensive sectors displaying the highest divergence in terms of productivity levels.

Overall this paper provides evidence of a more dynamic and healthier performance of the Brazilian manufacturing sector, that despite being dominated by NR industries value added, boasted a growth-enhancing structural chance that was mainly driven by R&D industries, and hence by the most dynamic sectors according to our classification.

Conversely, in Argentina, the predominance of NR industries value added is persistently higher over time with respect to the other two macro-sectors. Furthermore these sectors are the main responsible for structural change. If such productivity growth trajectory continues to persist, it is likely to accrue the low diversification and dynamism of the Argentine production structure, where the industrial policy has shown itself to be weaker and more discontinuous than in Brazil.

A clearer enforcement of R&D intensive industries productivity and value added is advisable both in Argentina, to a greater extent given its relatively weaker position, and in Brazil in order to promote structural change and help the diversification of the production structure. This would in turn reduce the vulnerability suffered by both countries bound to the volatility of the commodity prices, which should not constitute the only value added of the economy especially when adopting a long-term perspective. It is often the case that, in developing countries like Argentina and Brazil, farsightedness is uncommon due to trade-offs that often privilege short-term gains (due to the conspicuous presence of highly demanded commodities) by foregoing long-term opportunities. Ascher (2009) talks about this as dilemma, whereby developing countries need to overcome this short-sightedness through foresight policies tailored to the skills and abilities of policy makers, cultural setting, the quality and the size of the human capital and technological availability. This policy dimension of innovation and technology foresight will be addressed in *Chapter 4* of this dissertation. Coherent innovation policies should be inherently coupled with industrial strategies, and both are essential to encourage structural change while promoting productivity growth and employment in a sustainable manner.

Appendix A

Appendix A.1.
Summary statistics by macro-sector, Brazil

Table A.1.1.

Natural resources industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	162937.1	223474.2	69	1361344	N = 494
	Between		223769.9	217.7105	865777.4	n = 13
	Within		60214.36	-204538	658503.6	T = 38
Output	Overall	7321.008	8996.523	.18	42552.43	N = 494
	Between		8745.273	.3623684	27933.76	n = 13
	Within		3193.352	-7411.35	21939.68	T = 38
Productivity	Overall	73577.23	209624.5	2487.08	1979899	N = 494
	Between		170977.4	4142.047	634811.8	n = 13
	Within		130012	-299073	1418664	T = 38
Value added	Overall	2902.229	3089.326	46.4	13820.67	N = 494
	Between		2944.573	104.1711	10015.54	n = 13
	Within		1234.566	-2995.98	6707.363	T = 38

Table A.1.2.

Labour intensive industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	235557.7	165526.3	27752	932135	N = 380
	Between		152079.5	62396.24	558210.1	n = 10
	Within		80800.07	-100447	609482.7	T = 38
Output	Overall	3657.939	3092.07	141.55	13284.62	N = 380
	Between		2996.966	222.2021	10154.4	n = 10
	Within		1206.625	-326.714	7758.366	T = 38
Productivity	Overall	9068.346	6788.266	581.58	30992.08	N = 380
	Between		6401.676	864.1318	21561.33	n = 10
	Within		3016.608	2988.646	20478.55	T = 38
Value added	Overall	1877.8	1527.359	96.06	6184.68	N = 380
	Between		1486.835	137.0971	4560.305	n = 10
	Within		581.3475	87.55487	3960.813	T = 38

Table A.1.3.

R&D intensive industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	289346.9	146683.6	18560	584399	N = 190
	Between		145618.8	51800.84	429838.9	n = 5
	Within		66801.56	23177.04	460679.8	T = 38
Output	Overall	10946.48	9092.197	207.74	42653.22	N = 190
	Between		6858.908	1036.153	16453.13	n = 5
	Within		6695.762	-1591.67	37146.56	T = 38
Productivity	Overall	17024.44	9402.076	5164.25	49102.24	N = 190
	Between		7451.427	8622.037	27475.74	n = 5
	Within		6614	-113.825	38650.93	T = 38
Value added	Overall	5093.251	3578.313	143.88	16375.8	N = 190
	Between		3240.396	592.895	8475.528	n = 5
	Within		2088.001	-654.326	12993.52	T = 38

Appendix A.2.
Patterns of % growth in the manufacturing sector by macro-sector, 1970 2008, Brazil*

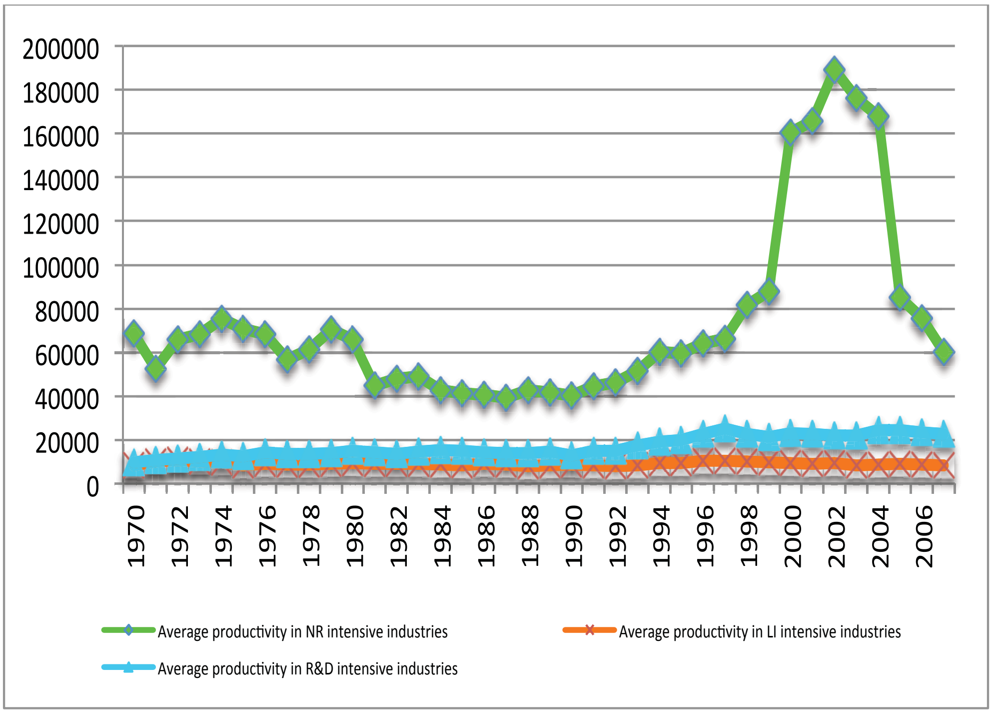
*Cells displaying a positive growth rate are highlighted in the same colours of macro-sectors adopted in the graphs in order to facilitate the numbers' interpretation.

Table A.2.1

Manufacturing sector, 1970-2007 by macro-sector, Brazil					
Period	Macro-sector	**Employment %**	**Value added %**	**Productivity %**	**Output %**
1970-1980	NR	**65.84**	-7.95	-26.19	-0.53
	LI	**74.47**	-20.78	-12.38	-25.87
	R&D	**124.72**	**46.75**	**21.21**	**39.23**
1981-1993	NR	-3.42	**7.77**	-10.35	-3.84
	LI	-16.80	-12.91	-27.61	-9.14
	R&D	-11.87	-0.02	-4.87	**8.58**
1994-2003	**NR**	**10.82**	**2.59**	**185.25**	-5.15
	LI	**3.53**	-14.75	-12.99	-15.80
	R&D	**1.84**	**6.48**	**11.14**	**20.02**
2004-2007	NR	**14.79**	-6.06	-61.78	-3.84
	LI	**6.91**	-4.45	**2.52**	-9.14
	R&D	**25.02**	**9.98**	-0.92	**8.58**

Appendix A.3.

Graph A.3.1.
Average productivity by macro-sector, Brazil

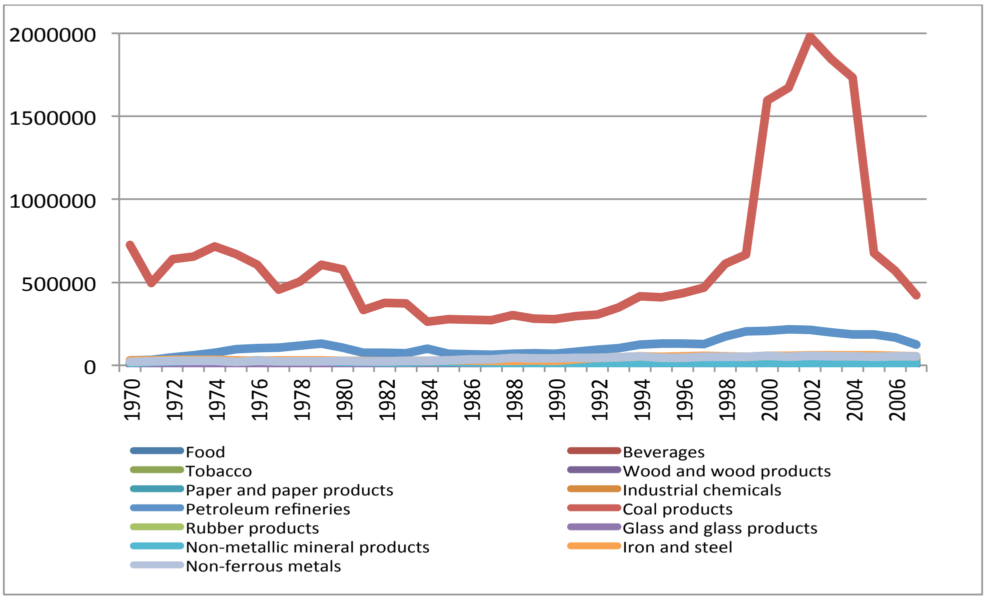


Appendix A.4.

Average productivity break-down within each macro-sector, Brazil

Graph A.4.1.

Productivity level within NR intensive industries, Brazil

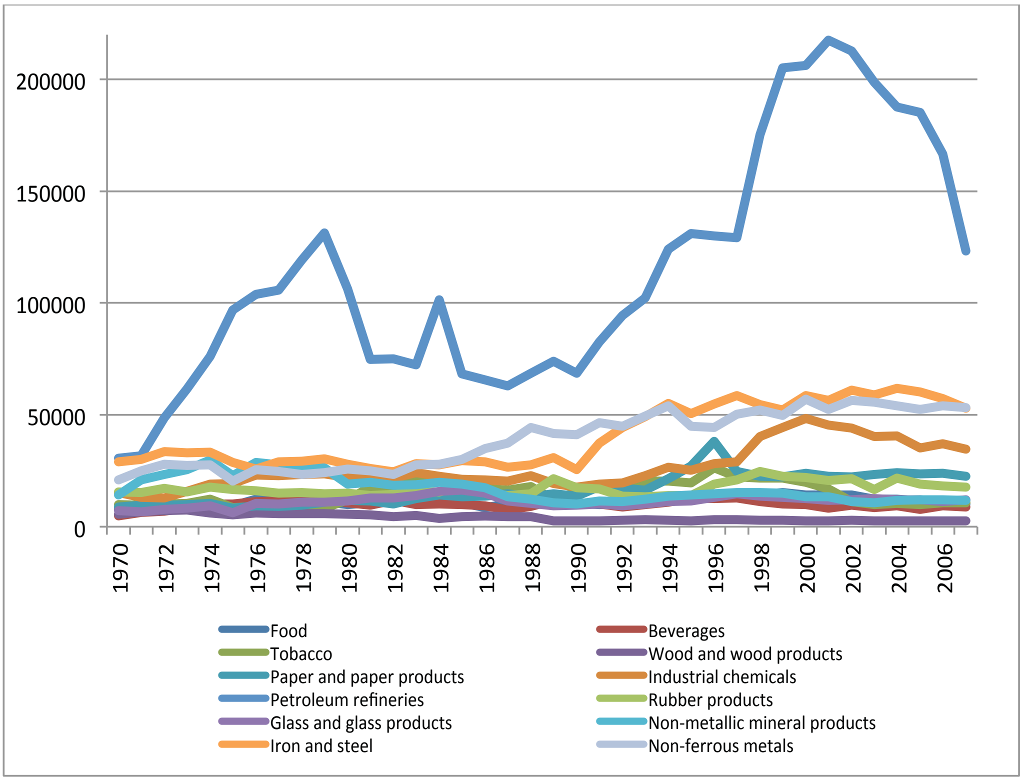


From the graph above it can be appreciated that in Brazil productivity growth within NR is mainly driven by coal industries.

If we take coal away from the graph the second most important sector is oil, followed by iron and steel, non-ferrous metals. The sectors displaying the lowest productivity level within NR industries also tend to be quite stable over time and they are wood and wood products, glass and glass products and beverages (se graph A.4.2.).

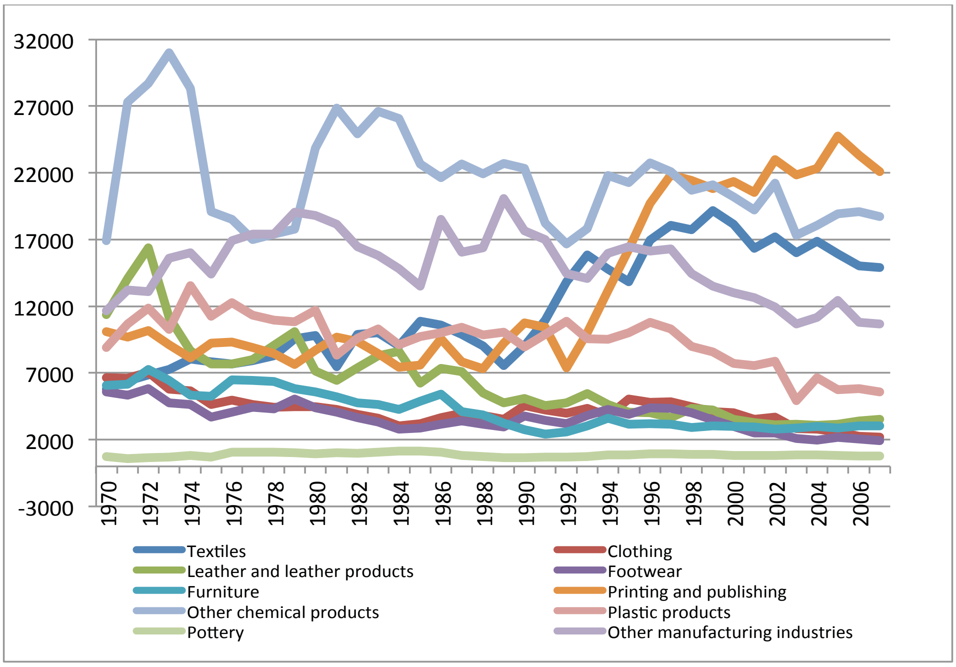
Graph A.4.2.

Productivity level within NR intensive industries (without coal), Brazil



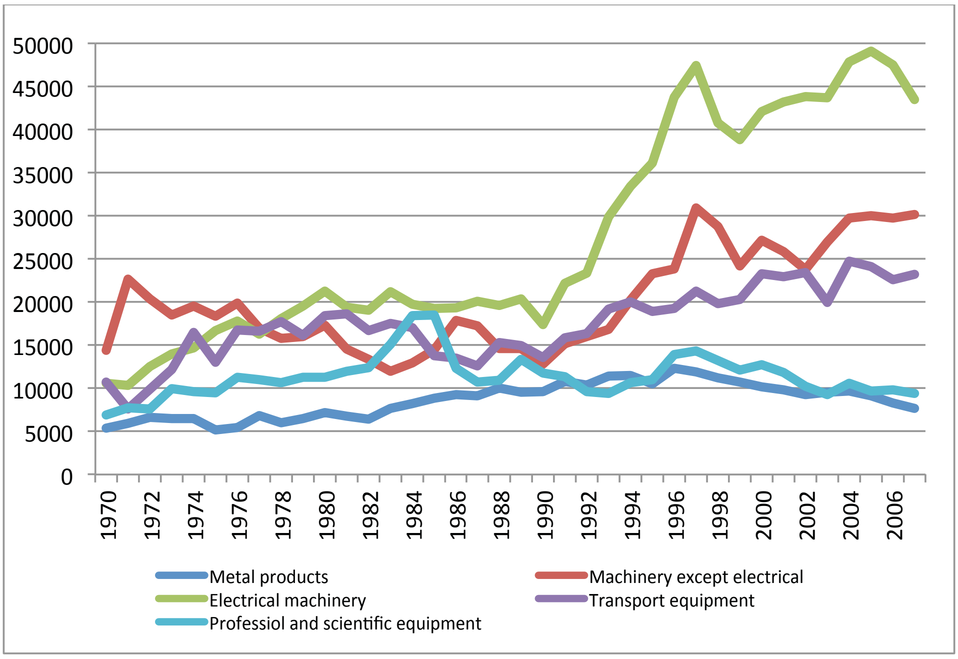
Graph A.4.3.

Productivity level within LI intensive industries, Brazil



In the LI group the top industries are printing and publishing, other chemical products, textiles and other manufacturing industries. The LI macro-sector, though, is also characterized by the overall lowest productivity levels, due to pottery, furniture and footwear.

Graph A.4.4.
Productivity level within R&D intensive industries, Brazil



Within the R&D intensive group the most important industries in terms of productivity are electrical machinery, machinery except electrical and transport and equipment.

Appendix A.5.
Summary statistics by macro-sector, Argentina

Table A.5.1.

Natural resources industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	38993.4	61737.91	122	297491	N = 494
	Between		63408.99	230.4211	242932.9	n = 13
	Within		9624.193	-2088.5	93551.45	T = 38
Output	Overall	3789.656	6319.316	93.04	35454.78	N = 494
	Between		6383.097	139.9553	24190.55	n = 13
	Within		1499.231	-2192.11	15053.88	T = 38
Productivity	Overall	61096.29	83032.86	5280.83	509426.2	N = 494
	Between		75676.29	9538.013	266285	n = 13
	Within		39967.03	-145469.	304237.5	T = 38
Value added	Overall	1177.635	1829.193	7.29	10726.31	N = 494
	Between		1830.683	59.33026	6913.473	n = 13
	Within		496.0537	-504.448	4990.471	T = 38

Table A.5.2.

Labour intensive industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	46704.24	39690.5	2649	199446	N = 380
	Between		31598.19	5465.132	101725.5	n = 10
	Within		25968.52	-13800.2	144424.7	T = 38
Output	Overall	1038.572	1451.847	33.84	5897.09	N = 380
	Between		1440.463	87.37816	4147.764	n = 10
	Within		485.2776	-1796.02	3545.854	T = 38
Productivity	Overall	10780.99	8851.339	1710.46	44377.29	N = 380
	Between		5538.177	3464.968	20656.45	n = 10
	Within		7118.224	-1473.22	44053.07	T = 38
Value added	Overall	534.659	496.8082	24.38	2395.26	N = 380
	Between		496.4632	69.14447	1696.268	n = 10
	Within		156.2208	97.75113	1233.651	T = 38

Table A.5.3.

R&D intensive industries		Mean	Std. Dev.	Min	Max	Observations
Employment	Overall	64180.56	44655.92	4883	176506	N = 190
	Between		36227.66	8314.474	96006.58	n = 5
	Within		30637.25	12796.98	155346.1	T = 38
Output	Overall	2408.215	1817.384	41.08	8204.71	N = 190
	Between		1799.663	202.11	5169.859	n = 5
	Within		835.5526	-186.824	5680.274	T = 38
Productivity	Overall	14978.13	7480.546	3274.24	36445.36	N = 190
	Between		5568.45	8510.885	23275.59	n = 5
	Within		5569.669	4676.965	31602.41	T = 38
Value added	Overall	957.2992	728.7768	43.77	3100.71	N = 190
	Between		743.858	58.03868	2076.892	n = 5
	Within		293.4515	96.68711	1981.117	T = 38

Appendix A.6.

Patterns of % growth in the manufacturing sector by macro-sector, 1970 2008, Argentina*

*Cells displaying a positive growth rate are highlighted in the same colours of macro-sectors adopted in the graphs in order to facilitate the numbers' interpretation

Table A.6.1.

Manufacturing sector, 1970-2007 by macro-sector, Argentina					
Period	**Macro-sector**	**Employment %**	**Value added %**	**Productivity%**	**Output%**
1970-1975	NR	**25.74%**	**0.83%**	-15.29%	-1.56%
	LI	**12.94%**	-5.02%	-1.64%	**0.25%**
	R&D	**21.66%**	**2.44%**	**3.51%**	**4.42%**
1976-1981	NR	-22.18%	**1.92%**	**9.00%**	**7.96%**
	LI	-38.17%	**4.45**	-8.10%	-12.88%
	R&D	-39.00%	-8.63%	-6.46%	-12.15%
1982-1990	NR	-8.77%	**7.38%**	**3.59%**	**5.56%**
	LI	-17.89%	**0.78%**	-2.99%	**3.49%**
	R&D	-16.81%	-24.66%	-22.12%	-26.13%
1991-2001	NR	-12.60%	-1.46%	-47.03%	7.83%
	LI	-23.87%	**5.71%**	**77.39%**	-24.44%
	R&D	-25.60%	-1.58%	**18.88%**	-15.20%
2002-2007	NR	**37.09%**	-3.38%	**2.71%**	-8.11%
	LI	**54.36%**	-9.20%	-2.25%	**17.61%**
	R&D	**87.44%**	34.33%	**17.74%**	**48.28%**

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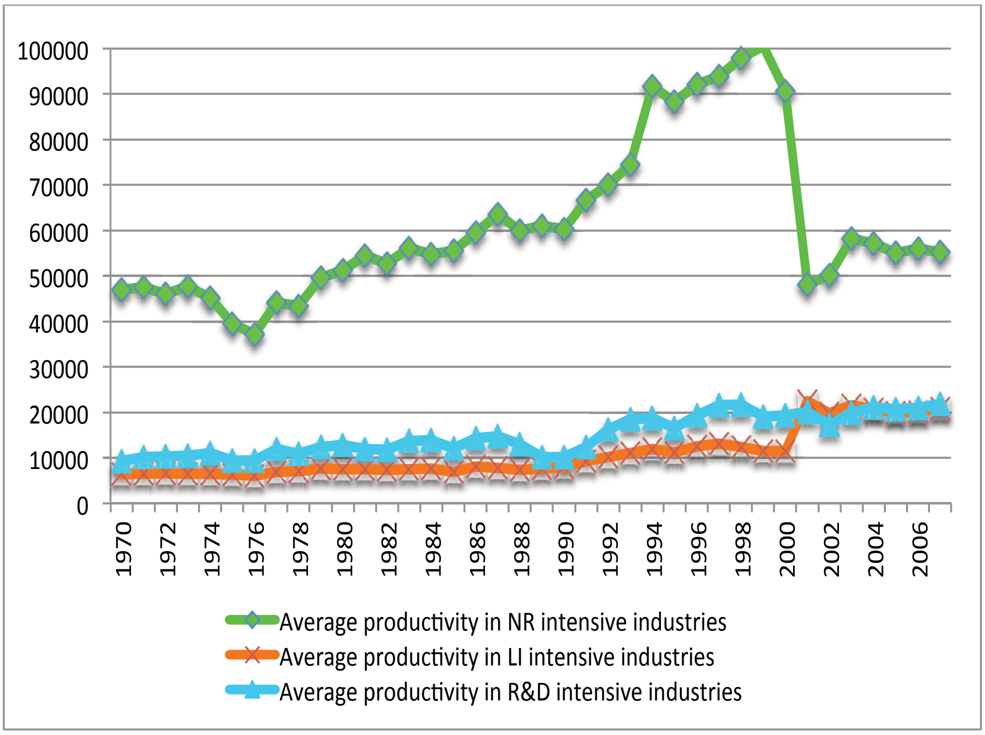
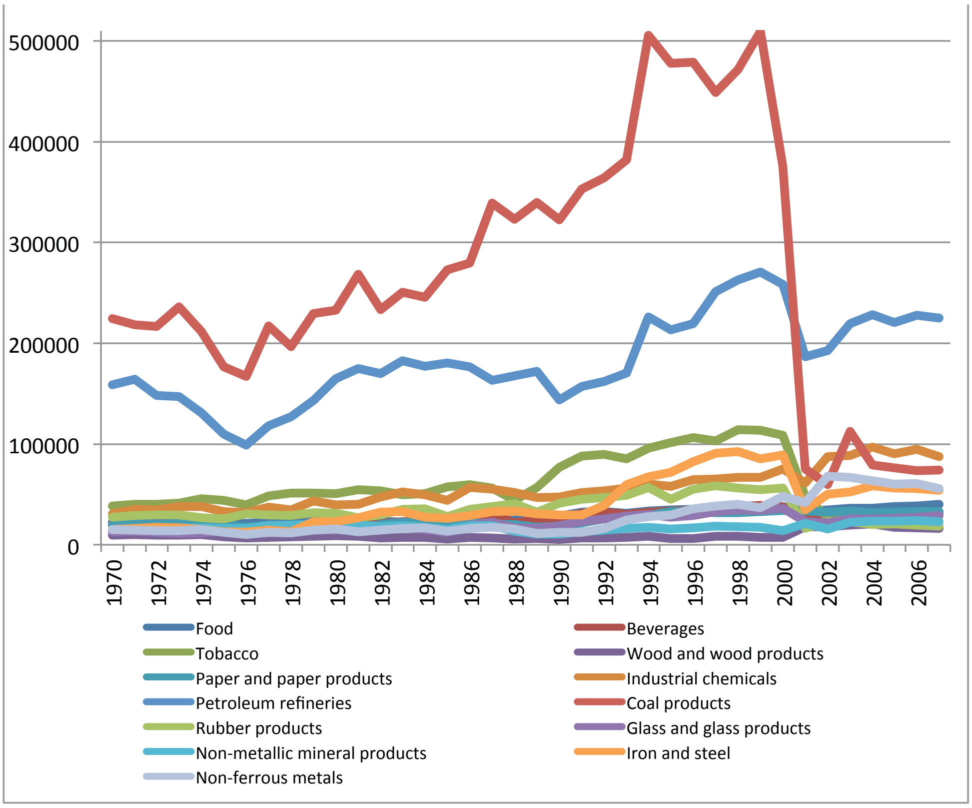
Appendix A.7.

Graph A.7.1.
Average productivity by macro-sector, Argentina



Appendix A.8.
Argentina average productivity break-down within each macro-sector

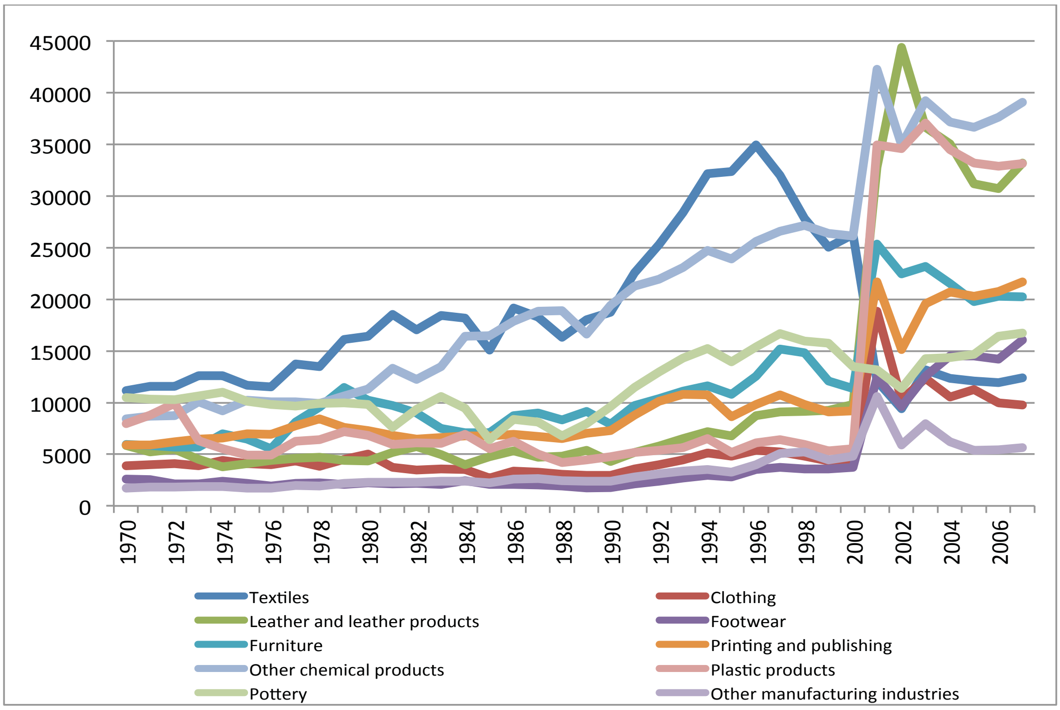
Graph A.8.1.
Productivity level within NR intensive industries, Argentina



Graph A.8.1. reveals that, similarly to what occurred in Brazil, the most productive industries within the NR macro-sector are coal, and oil and refineries followed by tobacco and steel. The least productive industries are wood and wood products, non-metallic mineral products and glass and glass products.

Graph A.8.2.

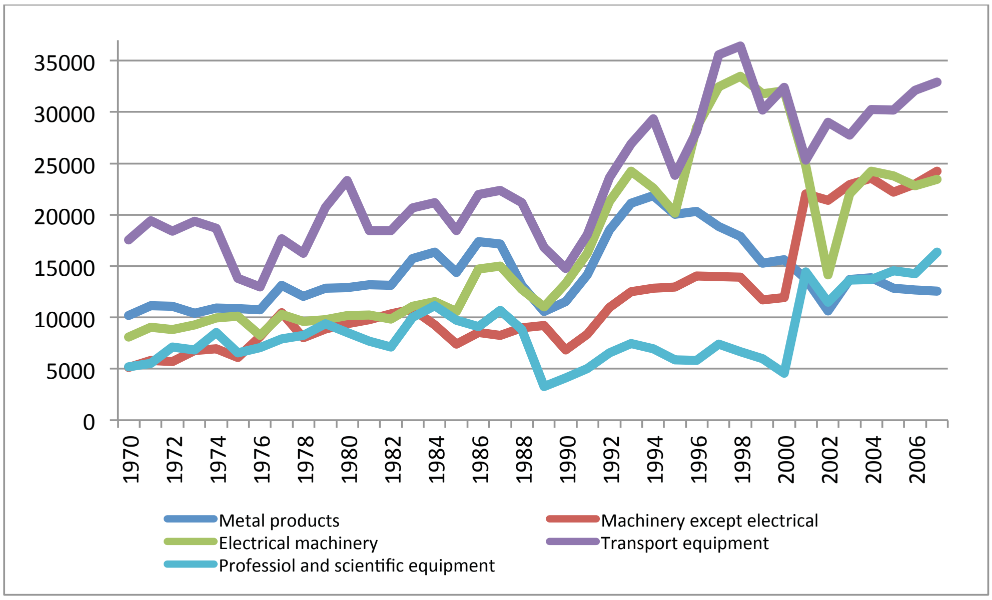
Productivity level within LI intensive industries, Argentina



In the LI group the top industries are textiles, other chemical products and leather products that experienced a dramatic rise in productivity after the 2001 crisis. The lowest productive sectors are: footwear, other manufacturing industries and clothing.

Graph A.8.3.

Productivity level within R&D intensive industries, Argentina



Graph A.8.3. portrays a similar trend with respect to Brazil in terms of top productivity sectors in the Argentine R&D intensive macro-sector. Top productivity industries are transport and equipment, electrical machinery and machinery except electrical

Chapter 3

3. The link between structural change and cross-sectoral wage inequality in the Brazilian and Argentine manufacturing sector

Abstract

This chapter examines whether, and if so to what extent, structural change impacts cross-sectoral wage inequality[18] in the Argentine and Brazilian manufacturing industries, arguing that sectoral specialization represents a key candidate in explaining such process.

It does so by linking the evolutionary and the labour market literatures in a new and complementary fashion to clarify in more detail the causes of cross-sectoral wage inequality from a macro-economic perspective.

First, we explore the data and the method to measure cross-sectoral wage inequality. Second, we examine which channels of structural change among productivity, gross margin and trade dynamics – including import penetration and trade openness - most significantly contribute to the generation of cross-sectoral wage *premiums*. Third, once the causes of cross-sectoral wage inequality are identified, we disentangle their effect at the macro-sectoral level. This will allow understanding whether the sectoral nature of these industries plays a role in generating higher - or lower - sectoral wage *premiums*. The obtained results indicate that trade dynamics within R&D intensive industries act as a springboard to generate higher sectoral wage gaps. The opposite holds true in the case of natural resources intensive industries.

[18] The terms "cross-sector wage inequality" and "sectoral wage gap/premiums" are used interchangeably. Both concepts can be essentially identified with the so-called "inter sectoral wage inequality" from Mahler *et al.* (1999) and Thewissen *et al.* (2013) - the two empirical papers we used as a reference for the analytical section of this chapter.

3.1. Introduction

Over the last three decades, labour markets in developing countries went through remarkable changes in terms of wage distribution along with the employment composition of the workforce. The issue of wage inequality has become crucial in order to foster a sustainable economic development.[19] Latin America has some of the most unequal countries, which can be seen as the outcome of several factors, among which the on-going process of globalization and structural change turn out to be the most important ones (Cornia, 1999).

By adopting a macro-economic perspective, this chapter investigates the effect of productivity, gross margin and trade dynamics -identified as channels of structural change - on cross-sectoral wage inequality in the Brazilian and Argentine manufacturing industries. To be able to reach this goal, we combine the evolutionary and labour market literatures in a new and complementary fashion. The former literature is essential to interpret structural change dynamics, whereas the latter is more suitable to address the actual causes of wage inequality.

We will use panel data on 28 Argentinian and Brazilian industries spanning 38 years (1970 to 2007). The data, Analysis Program of Industrial Dynamics (PADI, Katz and Stumpo, 2001), is obtained from the Economic Commission for Latin America and the Caribbean (ECLAC). A key advantage of PADI is the possibility of grouping the 28 industries (otherwise defined as "manufacturing sectors") into three "macro-sectors", according to their most used factor of production, namely: labour (LI), natural resources (NR) and R&D intensive industries (R&D).[20] Such subdivision is crucial since it allows understanding to what extent the "sectoral nature" of these industries influences the relationship between structural change and wage gaps. Such inequality epitomizes a recurrent concern both in Brazil and in Argentina. Allegedly, from the structural change viewpoint both countries can be regarded as textbook models of the so-called "Dutch disease". Their heavy reliance on

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[19] This challenge is identified as the core topic of the book "Structural change for equality" (2012, ECLAC) It epitomizes the renewed public scrutiny surrounding the topic of growth and inequality, previously addressed by authors such as Faijnzylber (1990), Furtado, (1961), and Prebisch, (1950).

The relationship between growth, structural change and wage distribution got elevated to a greater, renewed prominence with respect the past literature (as we shall see later with authors like Faijnzylber, 1990; Furtado, 1961 and Prebisch, 1950).

[20] Here the term "macro-sector" is the same as the concept of "sector" in the paper of Cimoli *et al.* (2006:31). However, in the current work the terms "sector" and "industry" are used interchangeably to indicate the 28 sectors composing the whole manufacture of the country.

natural resources shifts factors of production away from the more dynamic sectors (*i.e.* those with increasing returns to scale such as R&D and knowledge-intensive industries) which have the potential to enhance the region's flexibility to respond to demand changes. Additionally, the region is known for being one of the world's most unequal (Morely, 1995).

By identifying the predictors of structural change (*Chapter 2*) as well as their effect on earnings inequality (current chapter) we formulate policy recommendations contributing towards a more dynamic, sustainable and equal industrial development. In particular we will detect whether, and if so to what extent, workers can benefit from sectoral wage *premiums via* productivity, gross margin and trade dynamics, and whether these effects are significantly different, depending on the macro-sector in which the worker is employed. Furthermore, we will also be able to test and comment the results in light of the degree of wage inequality occurring within each of the macro-sectors.

The theoretical framework adopted in the current work, which primarily delves into the structuralist and Schumpeterian literatures, builds on the discussion of *Chapter 2* of this thesis addressing the evolution of structural change and productivity growth in Brazil and Argentina. Here too we stress the importance of the *sectoral* dimension of structural change, which regards economies as highly structured and heterogeneous. The findings gained from the *Chapter 2* serve as a platform for the current work and highlight two differing industrial development trajectories that see Brazil in a relatively more favourable position than Argentina. In fact, Brazil boasts a growth-enhancing structural change mainly driven by R&D industries, and hence by the most dynamic sectors according to our classification. Conversely, in Argentina, structural change is NR intensive industries-driven, a factor exacerbating the scant diversification and dynamism of its production structure. Here we take these results one step further by unravelling how cross-sectoral wage inequality reacts to different sources of structural change.

A careful review of the literature reveals a lack of studies in evolutionary economics on the distributional impact of structural change, especially from a sectoral perspective. Even though much attention has been paid to inequality trends at the country-, household- and/or worker-level, the literature fails to offer an adequate explanation of the causes of *sectoral* wage gaps.

Questions remain to what extent cross-sectoral inequality is a consequence of structural change *via* trade and/or productivity dynamics. This issue has been alarmingly disregarded even by Schumpeter (1942) whose theory on creative destruction of innovation was centred on the role of the entrepreneur rather than on its distributional consequences on the labour market. This gap found in the evolutionary literature justifies the inclusion of additional insights from the labour market literature, which helps identifying the causes of wage inequality in a more detailed fashion.

Yet, the labour market literature similarly suffers from limitations. For instance, the Skill-Biased Technical Change (SBTC) theory has proven an unsatisfactory explanation for wage inequality. If technology was the cause of higher inequality during the computerization of the economy, why did it not equally affect all countries where such technology penetrated? (Card and Di Nardo, 2002, and Lemieux, 2011). Clearly the joint dynamics of market frictions and multiple influences determine wages' evolution.

The following research questions illustrate how the link between structural change and cross-sectoral wage gaps will be analysed:

1) *What is the trend of cross-sectoral wage inequality?*
2) *Which potential factors, contemplated by the literature, most prominently contribute to the generation of cross-sectoral wage premium in the Argentine and Brazilian manufacturing sectors (jointly and separately considered)?*
3) *Does the effect of such factors differ depending on the macro-sector? Is the nature of the sector a suitable candidate in explaining how structural change affects sectoral* wages distribution?

We find that when structural change acts *via* trade dynamics in R&D intensive industries, sectoral wage gaps increase, whereas the opposite is true the case of NR intensive industries. These findings confirm the hypothesis that R&D intensive industries, by being more dynamic, presumably employing more skilled and protected workers, boast a relatively more direct transmission mechanism of structural change *vis a vis* higher wage gaps from which workers can benefit.

The remainder of the paper is structured as follows. Section 3.2. provides a brief literature review. Section 3.3. describes the data and the historical background of the two countries. Section 3.4. illustrates the descriptive statistics. Sections 3.5. and 3.6. present the identification of our main variables of interest and the empirical strategy. Section 3.7. presents the results and section 3.8. concludes.

3.2. Literature review

The literature review stretches over the theoretical and empirical contributions, structured as follows.

The theoretical section will provide the conceptual foundation of the current study:

- firstly, by illustrating how the evolutionary theory is essential in explaining structural change and how, nevertheless, it does not yet sufficiently address the issue of inequality;
- secondly, and consequently, by exploring the labour market literature to tackle the causes of wage inequality in a more detailed manner, filling the gap in the evolutionary literature; and
- thirdly, by combining the two literatures together in order to unfold the actual channels through which structural change impacts sectoral wage distribution, highlighting how they fit together in explaining our main research question.

The empirical section presents the analytical foundations for the empirical strategy of the study.

3.2.1. Theoretical literature: Structural change and wage inequality: an evolutionary perspective

Latin American Structuralism (LAS) and the Schumpeterian literatures, which fall under the umbrella of evolutionary economics, provide the ideal theoretical platform for analysing the impact of structural change on wages. Both literatures accentuate the *sectoral* dimension of economic development, linked to a country's ability to shift its resources from primary to more dynamic sectors, typically characterized by R&D and innovation. This changing specialization should positively impact employment, demand and ultimately generate more productive and better-quality/paid jobs as a result of a progressively and more rapidly evolving demand of consumption and capital, international competition and technological change (Cimoli *et al*., 2014).

Within LAS, Furtado's (1966) work best addresses the causality between structural change and income/wage distribution. The author maintains that the composition of sectoral investment and technological options are pre-decided by income concentration. In fact, the widely used setting for countries like Brazil and Argentina is a dual model composed by the more advanced *versus* the subsistence sectors. The former are usually based on exploitation of natural resources or isolated industrial activities targeted to exports, catalysing technical change and offering a production structure similar to that of developed countries. The latter are featured by low levels of productivity and employ the greatest part of the labour force. As a result, differences in sectoral productivity tend to be remarkable in developing countries ("structural heterogeneity") since the production is mainly supported by the discovery and exploitation of natural resources.

Furtado's (1966) analysis, along with the work of such subsequent scholars as Faijnzylber (1990), point to a positive direct causality between structural heterogeneity and unequal wage distribution among workers, sectors and regions (Bielschowsky, 2010). In their view, the unequal capital/technological penetration leading to diverging productivity levels would in turn feed the vicious circle of unbalanced growth, underemployment and, since productivity should reflect wages, of unequal wage distribution.

If one country's production structure is far from the technological frontier, then a great amount of the workforce remains at the margins of technological progress, or else moves into low value-added professional services or stays unemployed (Prebisch, 1950, and Furtado, 1961). Conversely, in advanced economies where technology, thanks to spill-over effects, is likely to penetrate more evenly across sectors, marginal productivity tends to equalize among sectors, as do wages.

Fajnzylber (1990) added further insights to explain the relationship between economic growth and income distribution. Using data from 1970-1984, he divided countries into three groups: those with an accelerated growth but high inequality; those more equal but with poor economic growth; and those with poor growth and high inequality. None of the Latin American countries was positioned in the ideal growth path: high equality and high growth; unlike, for instance, Korea and Hungary.

Finally, from an evolutionary perspective, structural change is well epitomized by the concept of "creative destruction" (Schumpeter, 1942). Such process can be regarded as the concrete manifestation of technological progress and its consequent disruptive effects on older technologies and/or ways of production. By this, Schumpeter was referring to an economy as not in a static equilibrium, but rather continuously being disrupted by technological change.

So far we have discussed the suitability of the evolutionary literature in describing the macro dynamics of structural change and its impact on wage inequality. However, this approach did not sufficiently address the actual *causes* of unequal wage distribution, an issue taken up the next section illustrating how the labour market literature can fill in this gap.

3.2.2. Wage inequality: a complementary perspective from the labour market literature

The adoption of the evolutionary literature is based on its suitability in addressing the underlying macro-economic factors responsible for the persistent asymmetries and complexities in the production structure and capabilities that ultimately generate cross-sectoral inequality. Yet, by adopting solely an evolutionary framework, some specific dynamics regarding the actual *causes* of wage inequality are overlooked and in turn better explored by the labour market literature. The added value of this work lays precisely in the ability to incorporate the useful insight from the labour market literature to improve the explanatory power of the evolutionary theory to fully grasp the macro-economic determinants of wage inequality. In such a way we fill in some major literature gaps both from the evolutionary - as we have seen in paragraph 3.2.1. - and the labour market perspective - as it will be described below.

The labour market literature typically examines wage inequality dynamics from a micro-perspective with an in-depth approach focusing on workers' characteristics (such as age, experience, education, gender, etc.) but with a short time frame (roughly from 5 to 10 years).[21] Such a short time frame impedes the understanding of how the macro-dynamics of economic specialization impact wages, which are instead clearer with a longer time frame and with a sectoral perspective. To study wage distribution without understanding the underlying structural change dynamics is likely to provide a narrow view of the overall picture, at least from a macro-perspective.

Despite the above-mentioned limitations, the labour market literature benefits from a more consolidated focus on the actual causes of wage inequality which can be divided into the demand and the supply of labour. In the latter group, all the aspects that directly or indirectly affect the workers' characteristics such as education, age and experience are included (Acemoglu and Autor, 2010, and Autor *et al.*, 2008). The former group encompasses all those factors affecting the demand of labour and will be explored in the current study by delving on the role of technology (Acemoglu, 2002; Howell and Wieler 1998; Card and DiNardo, 2002; Katz and Autor, 1999; and Caselli, 2014) and trade (Wood, 1994; Corsini, 2013; and Sampson, 2014).

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[21] The workers' observable characteristics are typically regressed on the logarithm of wages in order to account for the so-called "between-group" wage inequality (*i.e.* Acemoglu and Autor, 2010, and Autor *et al.*, 2008, etc.). The inequality that is not explained by these observable characteristics is called "within-group" or "residual" wage inequality and originates from workers' unobservable skills (*i.e.* personal abilities or particular talents) (Juhn, *et al.*, 1993).

The next paragraph presents a taxonomy unfolding the channels through which structural change impacts wages in more in detail, blending together the two literatures and highlighting their complementarity to the purpose of this research.

3.2.3. Channels through which structural change impacts wages: bridging the labour market and evolutionary literature for a common goal

Having so far examined the theoretical arguments for adopting an evolutionary and labour market perspective, the research now turns to the actual channels of causation between structural change and cross-sectoral wage inequality, drawing from both literatures (see Table 3. 1. for a complete summary). Structural change *per se* does not affect wages in a clear unilateral manner, since it results from a variety of forces and economic policies that are mutually influencing and whose effect is largely contingent on the sectoral specificities of each economy (or region, or sector).

Within the labour market literature, Skill-Biased Technical Change (SBTC) (Katz and Autor, 1999) and trade openness (or liberalization) (Wood, 1994) became two dominant explanations for higher and lower wage inequality respectively.

On the one hand, SBTC does not regard technology as skills-neutral, but rather as skills-biased, as it tends to be skill-complementary. Hence more skilled workers are paid a wage *premium*, thereby inducing an overall increase in wage inequality. Our empirical setting (section 3.5.) allows testing the SBTC hypothesis but on a macro-level and indirectly. In fact, the information accounting for innovative activities, is the sectoral subdivision in R&D intensive industries, wherein we try to detect whether structural change dynamics exert a different impact on cross-sectoral wage gaps in comparison with the other two macro-sectors.

On the other hand, trade liberalization is based on the predictions of the Heckscher-Ohlin model according to which greater openness should decrease inequality and enhance efficiency in developing countries. This theory builds on the notion of open trade and comparative advantages, whereby developing countries should specialize their production on goods that are intensive in unskilled labour, of which they are richly endowed. This would increase wages of unskilled workers and, all else being equal, reduce wage gaps (Wood, 1997). In our model (section 3.6) we account for trade dynamics by firstly including import penetration and then trade openness as potential candidates explaining cross-sectoral wage gaps.

Finally, two useful frameworks to analyse the causes of wage inequality from a macro-economic and evolutionary point of view are provided by respectively Kuznets (1955) and the LAS.

Kuznets argues that, as an economy develops, market forces first increase and then decrease inequality. Specifically, in pre-industrial societies, almost everybody is equally poor, so inequality is low. Subsequently, inequality will rise as workers move from low productivity agriculture to the most productive industrial sectors where the average income is higher and wages are less homogenously distributed. As societies mature and become richer, urban-rural inequality is reduced.

In a similar vein, the LAS literature foresees a dual economy with the developed centre characterized by high levels of productivity and wages, and the backward periphery featured by a great amount of the workforce that remains at the margins of the technological frontier earning low wages. The generation of intermediate sectors is seen as a concrete effort not only to diversify the production structure, but also to reduce wage disparities among the leading and backward sectors. In our framework, the generation of intermediate sectors is conceived as the increased dynamism of R&D intensive industries which enables the economy to reach the technological frontier.

Table 3. 1.

Matrix: channels through which structural change impacts wage inequality		
	Channels through which structural change impact wage inequality	**Wage inequality expected sign**
Structural change	**SBTC** Routine-biased technical change	(+) Technology is skill biased. Relatively more skilled workers, wage *premium* (+) Technical change is biased toward replacing routine task, decreases the demand for middle-skills relative to high-skills occupation (Katz and Autor, 1999 and Card and Di Nardo 2002).
	Trade (Heckscher-Ohlin) Globalization Offshoring Openness/import penetration Real exchange rate appreciation	(-)Trade greater openness, should decrease wage inequality and enhance efficiency in developing countries. For its capacity to generate a reduction in inequality, HOS theory has been often invoked as a justification for trade liberalization policies in developing countries (proved wrong by many empirical works, see Wood, 1997; Lawrence and Slaughter, 1993; Haskel, 2000 and Dollar and Kraay, 2001). (+) Offshoring (+/-) Real exchange rate
	Economic growth, (Kuznets, 1955)	(+, -, +) Economic development at its initial stages first increases, reaches the peak and then decreases wage inequality which is represented by an inverse U shaped curve. Kuznets conjectured that the pattern was caused by a dual economy dynamic with the shift from the agricultural to the industrial sector.
	Change in the composition of the production structure (Structuralism and Neo-structuralism, ECLAC)	(-) In a dual economy there is a large fraction of workers employed in the informal and low productivity sector. Also there is a leading sector high productive sector, typically natural resources related. Structural change will help create intermediate-type of sectors between the leading and the backward sectors. Workers will move from one sector to the other, decreasing the overall inequality.

Source: own elaboration based on the analysed literature review

3.2.4. Relevant empirical contributions addressing structural change and cross-sectoral wage inequality

This paper aims at extending and connecting two empirical works examining structural change and cross-sectoral wage inequality.

From the structural change perspective we draw from Cimoli *et al*. (2006) who, in line with the findings gained from *Chapter 2* of this dissertation and also by using the PADI database, identified two different growth strategies based on the level of technological capabilities and complexities of countries' production structures. The Latin American economy, usually focused on extracting rents from abundant natural endowments or labour, is featured by marked productivity and wage distribution asymmetries in comparison with developed countries that, instead, tend to generate profits *via* innovation and technological development (*ibid*). Their central argument is that in order for developing countries to generate a virtuous export-led growth, and hence reduce the technological gap with the most advanced economies, a shift in the composition of the production structure towards R&D intensive industries is imperative since it enables higher rates of growth. Their approach is inherently interconnected to the current one, because we are interested in understanding to what extent the macro-sectoral nature of the industries under analysis - among which the R&D ones have the potential to trigger these high rates of growth and spill-over dynamics - played a role in generating wage *premiums*.

From the sectoral wage inequality viewpoint we refer to two empirical papers based on Luxembourg Income Study (LIS) countries. The first, Thewissen *et al*. (2013), investigated earnings inequality and employment at the sectoral level for eight LIS countries[22] (1985-2005) and found earnings inequality to be more pronounced within rather than between sectors. Yet they identify significant variations in the level of inequality across sectors. Furthermore, using a cross-sectional pooled time-series analysis, the authors provide evidence of a significant association between the exposure to imports and employment decline in within sectors inequality, while they do not find evidence for the relationship between within sectors inequality and international trade or skill-biased technical change (*ibid*).

The second study, Mahler *et al.* (1999), focused on cross-sectoral wage inequality by addressing the relationship between international integration and domestic

[22] Luxembourg Income Study (LIS) is a datasets on household- and person-level data on market and government income, demography, employment, and expenditures from countries in Europe, North America, Latin America, Africa, Asia, and Australia.

inequality in the developed market economy during the 1980s and the 1990s. To this purpose they analysed disaggregated data at a sectoral level and tried to detect the impact of imports, exports, inbound and outbound investments' flow and stock on wage inequality. Their results show few significant relationships between trade, investment and within sector wage distribution, concluding that economic globalization was not a key factor in explaining recent trends in income inequality in the Western world.

To the best of our knowledge, the empirical literature fails properly to address the relationship concerning structural change and the cross (or between) sector wage inequality. On the one hand, the issue has been under-explored in the Latin American context.[23] On the other hand, for what concerns the studies in LIS -as well as other developed - countries, the research has addressed the causes of the within-, rather than the between-sector wage inequality, showing that both international trade and skill-biased technical change were not its key causal factors.

Our approach is – to a certain extent - new to the existing literature owing to the fact that its main goal is to examine the determinants of structural change on the "between-sectors" – wage inequality. In contrast, the existing literature has extensively explored the "within sector" earning inequality in Argentina and Brazil, overlooking what causes earnings disparities between sectors.

This paper has several advantages over these contributions. The most important lies in the novelty of bridging the labour market with the evolutionary literatures facilitating the understanding of how structural change - a concept under which we encompass the values of productivity, gross margin, trade openness and import penetration – affects cross–sectoral wage distribution. In particular, in line with the LAS and Schumpeterian literatures, we ascertain whether these impacts are significantly different across macro-sectors. In this way it is possible to assess whether, and if so to what extent, R&D, LI and NR industries' wages *premiums* respond differently to macro-economic structural changes.

Additionally, with respect to previous works we benefit from greater extension of the time frame -38 years - a key element to study the impact of structural change on wage inequality thoroughly.

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[23] The major contribution on sectoral wage inequality comes from Galbraith and Cantú (2001) that nevertheless did not make the effort to address the actual *causal relationship* between their object of study - political regimes and turmoil - and wage inequality (measured by the Theil index). Their conclusions are limited to the observation of Theil index over time and paying special attention to its sensitivity to political and institutional changes. Interestingly, their work provide evidence that the level of between-sector wage inequality can be a good proxy for the within sector wage inequality.

3.3. Data

The study is based on the PADI covering 28 manufacturing sectors from 1970 to 2007 classified according to the International Standard Industrial Classification (ISIC rev. 3) for Brazil and Argentina. The 28 industries can be categorized into three main macro-sectors according to the most used factors of production, namely:

- NR intensive industries: 13 sectors;
- LI intensive industries: 10 sectors; and
- R&D intensive industries: 5 sectors.[24]

Such division is crucial since it enables understanding whether the impact of structural change varies in relation to the macro-sector in which it occurs. The sub-specification of each macro-sector is presented in Table 1.1.

Due to their most intensively used factor of production, R&D intensive industries can be considered the most technologically intensive ones (Cimoli, *et al*., 2006 and Katz, 2001).

The database contains aggregated data for 28 manufacturing sectors at constant prices (1985 as base year) for a number of variables, among which those that will be used in the current work are:

- imports (million US$, current prices);
- exports (million US$, current prices);
- gross output (the sum of the value of goods produced in the country, including the value of intermediate goods used in the production, million US$,
- employment (number of people);
- wages (million US$); and
- gross margin (the gross profit of enterprises measured as the difference between revenue and fix as well as variable costs of production, excluding administration, sales and R&D costs, million US$, constant prices).

3.3.1. Historical context: excursion

This section illustrates the key historical events that mostly affected the industrial performance of the two countries, a crucial step to contextualize our results (for a more in depth historical review refer to the introductory *Chapter 1*, section 1.4.).

Both countries experienced similar industrial policies and crises, namely:

[24] For the classification refer to Cimoli *et al.*, 2006, Table 1.4. in the introduction.

- The ISI period took off around the 1950s until the end of the 1970s and it involved a remarkable state participation in the economy, largely supported through foreign debt, subsidies and tariff barriers (Bielschowsky, 2010). Imports were substituted by domestic production, which strengthened remarkably. In this context the manufacturing sector was relatively sheltered from external competition reducing the technological gap with the frontier (Cimoli *et al*., 2014).[25]
- The debt crisis of the 1980s led to a period of recession that lasted until the beginning of the 1990s. This phase revealed the unsustainability of the previously chosen model, to finance economic development with external savings (*ibid*).
- The 1990s witnessed the implementation of a set of neoliberal policies that were opposite in their nature to those of ISI. Such policies aimed at promoting deregulation, privatization, open trade and liberalization of the financial flows, whereby the role of the state was largely downplayed by free market dynamics. The paradox is that during the 1990s productivity growth for most of LA countries accelerated, while the specialization patterns tended to move towards low-tech industries (*ibid*).

Despite similar reforms experienced by both countries, two major differences deserve special attention. The first is that Brazil has been more committed to industrial development than Argentina, since its ISI endured throughout the 1970s. Conversely, Argentina interrupted ISI in the late 1970s by endeavouring an early attempt of trade liberalization (*ibid*).

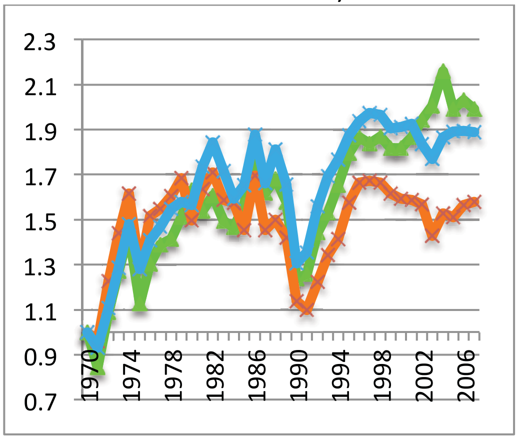
The second dissimilarity lies in the diverging use of the exchange rate policy by the two countries (Novick and Tomada, 2007). After the 1990s, Argentina adopted a fixed exchange rate that led to the greatest social and economic crisis in its history in 2001 (Cimoli *et al*., 2014). Conversely, Brazil embraced a band of fluctuation for the nominal exchange rate which provided more freedom to devalue and flexibly react to external shocks (*ibid*).

[25] Allegedly, Cimoli and Katz (2003) highlighted the Argentine case, whose automotive industry was internationally considered as an example of production excellence.

3.4. Descriptive statistics. Wage per worker by macro-sector[26]

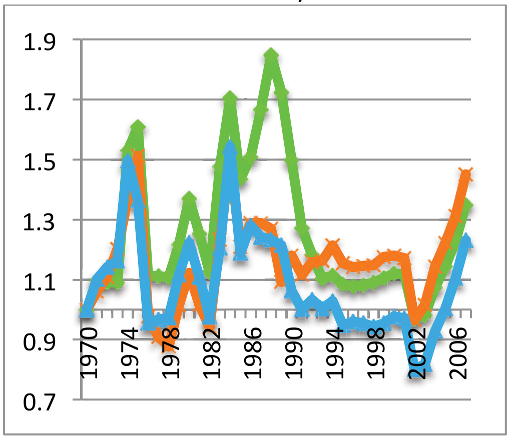
Graph 3.1.

Evolution of average wage per worker by macro-sector Brazil (average by macro-sector)



Graph 3.2.

Evolution of average wage per worker by macro-sector Argentina (average by macro-sector)



NR wage per worker LI wage per worker R&D wage per worker

Graphs 3.1. and 3.2. plot the average wage per worker by macro-sector in Brazil and Argentina as a result of the total wage divided by the total employment of each sector. The values are then normalized with respect to 1970, in order to better grasp the changes of the variable over time.

In Brazil (Graph 3.1.) R&D intensive industries display on average the highest wage per worker over the whole period, as well as the highest wage increase (96% from 1970 to 2007). Nevertheless, NR wage per worker shows almost the same level of R&D industries, with a minor bifurcation starting from the 2000s, the period of commodity boom, when R&D wages start to decrease relatively to those NR industries.

In Argentina (Graph 3.2.) average wage per worker rose dramatically (by 87%) during the first five years of analysis, 1970-1975, right before the military coup. This was the ISI period where wages were under protection in order to support domestic consumption, encouraging strong social integration, with occupation levels near to the full employment (Kosacoff, 2007). On the other hand, during open trade in the 1990s, the export-oriented policies forced firms to compete with

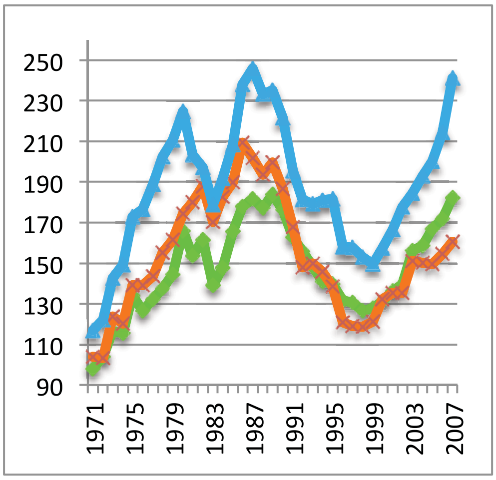
[26] All graphs and tables' sources are the outcome of our own elaboration on the basis of PADI (Katz and Stumpo, 2001) database- UN, ECLAC.

lower wage economies, leading to a drop in the average wage per worker by 44% from 1988 to 2001. Contrary to Brazil, in Argentina the highest paid sectors are NR intensive industries, followed by LI and R&D intensive ones.

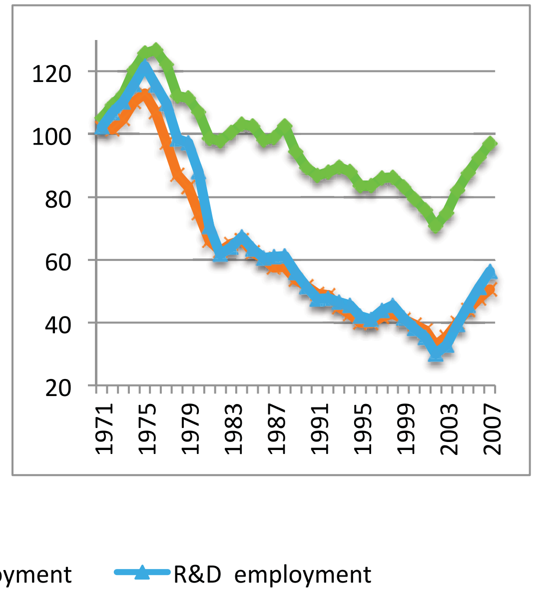
3.4.1. Employment by macro-sector

Graphs 3.3. and 3.4. display the employment level by macro-sector, normalized with respect to 1970.

Graph 3.3.
Evolution of employment by macro-sector Brazil (sum by macro-sector)



Graph 3.4.
Evolution of employment by macro-sector Argentina (sum by macro-sector)



In Brazil (Graph 3.3.) R&D intensive industries reveal the highest employment as well as the highest employment growth throughout the whole period –rising by more than 100% from 1970 to 2007 –as opposed to 85% and 54% growth in NR and LI industries respectively. From 1970 to 1994 employment was the second highest in LI industries. Only towards the end of the 1990s, NR industries' employment offsets that of LI industries. Once again, this trend proves a more pronounced dynamism of R&D intensive industries, not only in terms of wage growth but also of employment generation. Overall, the greatest decrease in employment occurred during trade liberalization in the 1990s, where the new outward-oriented competitive setting that went along with massive influx of import substitutes, led to the disruption of many industries and, by consequence, of many jobs.

Employment in Argentina (Graph 3.4.) increased, on average by 20%, only during the first half of the 1970s and after the major devaluation of 2001. ISI protected manufacturing employment from foreign competition as its value reached the peak in 1975, in spite of the very low productivity levels of that period. Nevertheless, between 1976 and 2001, employment dropped in all industries on average by 58%. The most affected industries were the R&D, followed by LI and NR intensive ones: their employment decreased by 69%,65% and 40% respectively (see Novick, and Tomada, 2007 and Katz and Kosacoff, 1989). Such a reduction of work places was associated with a rise in productivity, especially in NR.[27] The main difference with Brazil is that NR industries after the military coup are the most employment absorbing. Furthermore, the process of employment loss from the manufacturing industries began much earlier in Argentina, in the 1980s, than in Brazil, the 1990s.

3.5. Measurement of the main indicators for the econometric model

After understanding the trend of the macro-sectoral wages and employment (which are used for the construction of the dependent variable in section 3.5.1.) this paragraph illustrates the main indicators that will be included in the econometric model. Section 3.5.1. focuses on the dependent variable - the measure of cross-sectoral wage inequality (or wage gaps) (Mahler *et al.*, 1999 and Thewissen *et al.*, 2013), whereas section 3.5.2. describes the covariates representing structural change (PADI, Katz and Stumpo, 2001).

3.5.1. Dependent variable: sectoral wage inequality

Our measure of sectoral wage inequality draws from Mahler *et al.* (1999) and Thewissen *et al.* (2013) who calculated it as the logarithm ratio between the average income in a given sector and the median income of the country as a whole. The application of the same approach to our dataset has been conceived as the ratio between the average wage per worker in sector *i* at time *t*, divided by the median wage per worker of the macro-sector at time *t*, enhancing the comparability of wages among relatively similar groups of sectors and, supposedly, of workers.

[27] This is the so-called "spurious growth" indicating that the increase in productivity level is due to a loss of employment rather than increase in output Furtado,1961).

The measure of sectoral wage inequality is expressed as follows:

$$log\ wage\ gap_{it} = \log \frac{\bar{w}_{it}}{median\ w_{jt}} \qquad (1)$$

where *i* indicates the sector, and *j* the macro-sector to which the sector *i* belongs. In this way the inequality that we capture is a measure of per workers' average wage dispersion with respect to the median wage by macro-sector at 3-digit ISIC sectors.

When compared with other indicators of sectoral wage inequality such as the Theil index (Galbraith and and Cantú, 2001) this measure has the advantage of providing a value of wage gap for each year and each sector, which can be easily incorporated in a panel analysis.

The conceptual definition of "sectoral wage dispersion" is crucial at this stage of the study as it enables the understanding of its value added - as well as its weaknesses - in comparison with the existing literature on wage inequality.

Wage dispersion can be thought of having a between and a within component. Imaging a scenario with 2 persons (A, B) and two sectors (a and b). Personal income data could be decomposed in total income differentials. Precisely, the dispersion of wage between an individual in sector a and an individual in sector b can be expressed as:

$$YA,a - YB,b = (YAa - Median\ Ya) + \left(Ya - Median\ Ya \right) - \qquad (2)$$
$$(Yb - Median\ Y\ b) + \left(YBb - Median\ Yb\right)$$

The first and fourth brackets represent the within sector inequality and compare the median wage per worker of the sectors a and b with the actual wage per worker of respectively worker A and B. The second and third brackets indicate wage inequality not within, but between industries and compares average wage per worker in sector *a* and *b* with the median wage per worker in sector *a* and *b* respectively. This is precisely the type of inequality that this paper is defining across all the manufacturing industries and accounting for the median wage by macro-sector. Therefore our results should not be confused with the dispersion of personal wages, as data at a worker level is, unfortunately, not available for such a long time frame.

3.5.2. Main independent variables: definition of structural change

In order to disentangle the impact of structural change on cross-sectoral wage gaps, this section presents our definition of structural change which is represented by productivity, gross margin, import penetration and trade openness. The first two indicators are readily available from PADI (Katz and Stumpo, 2001):

productivity is the result of output divided by employment; and gross margin is the gross profit of enterprises resulting as the difference between revenue and fixed as well as variable costs of production, excluding administration, sales and R&D costs (*ibid*).

The other two indicators of trade dynamics are the outcome of our own calculations. The first, import penetration[28] (Mahler *et al*., 1999 and OECD, 2011 and Katz and Stumpo, 2001 2001), is expressed as:

$$import\ penetration = \frac{import_{it}}{output_{it}} \qquad (3);$$

and indicates to what extent the demand of goods is being met by foreign producers rather than from domestic production.

The second measure of trade dynamics is trade openness (PADI, Katz and Stumpo, 2001) calculated as:

$$trade\ openness = \frac{(export_{it} + imports_{it})}{output_{it}} \qquad (4);$$

and it reveals the extent of outward orientation of the industrial sector.

3.6. Empirical approach: panel estimation

This research essentially asks how structural change impacts sectoral wage gaps and whether it does so in an incrementally detailed fashion. Firstly it examines whether and to what extent, channels of structural change among productivity, gross margin and trade dynamics – including trade openness and import penetration- most prominently contribute to the generation of cross-sectoral wage *premiums*.

Secondly, once the causes of cross-sectoral wage inequality are specified, we disentangle their effect at macro-sectoral level for the trade-related covariates. This will allow understanding of how and to what extent the nature of these industries plays a role in generating higher - or lower - cross-sectoral wage *premiums via* trade dynamics.

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[28] To construct the index of import penetration, the OECD (2011) and Mahler *at al.* (1999) use total domestic demand gross domestic product as a denominator respectively. In the current work adapt these *formulas* to our database and we will refer to the level of output which is more in line with Mahler *et al.* (1999) since it offers an indication of how much of the industrial production (the industrial version of the GDP) is due to imports. This is ultimately the same index proposed by the PADI user manual (PADI, Katz and Stumpo, 2001:22).

The close correlation between trade openness and import penetration motivates the division of the panel into two “sub-models” (see Tables B.2.1. and B.2.2. in Appendix B). The first includes import penetration, whereas the second takes into account trade openness, holding every other aspect constant.

The sample consists of two countries Argentina and Brazil whereby the unit of observation is the industrial sector from 1970 to 2007. The methodology adopted here is an extension of Mahler *et al*. (1999) and Thewissen *et al*. (2013). Yet instead of limiting ourselves to a cross-section estimation, we opted for panel fixed effect estimation that allows controlling for unobserved sector-specific effects that are fixed over time (Wooldrige, 2009).[29] This type of estimation benefits from reducing the impact of time on the data, highlighting the variation between the unit of observation, which in our case is sector *i.* Common unobserved characteristics that differ across sectors, but are constant over time – or time invariant characteristics – can include the organizational structure of sectors, their factor intensities, their regulatory framework, etc. Such sectors' specificities are supposed to impact the sectoral wage gap and hence the possibility to control them, enhances the preciseness of our estimation remarkably. In order to deal with the issue of endogeneity, all covariates are lagged by one period.

The inclusion of the lagged value of the dependent variable within a fixed-effect panel estimation is not a usual praxis as it could be correlated with the idiosyncratic error, leading to a biased estimation. Nevertheless the bias is, to a great extent, wiped out when the panel boasts a considerable long time frame - as in our case (Wooldrige, 2002).

To test the robustness of the results, we performed the analysis with an alternative estimator, called GMM Arellano Bond (1991). The GMM procedure allows using lags of the variables (including the dependent variable) as regressors, as well as instrumental variables to control for bias due to the potential endogeneity of these regressors and the lagged dependent variable. Arellano Bond estimation assumes the existence of a correlation between the independent variables and the error term and the absence of any second-order autocorrelation.

Both types of procedures – panel fixed effects and GMM Arellano Bond- are consistent and lead to similar results. For this reason and for the suitability of the dataset to be analysed with a panel fixed-effect model, we opted for showing the results of the panel estimation (while the GMM results are shown in Tables B.5.1. and B.5.2. in Appendix B.5.).

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[29] The data structure comprises 28 sectors observed for 38 years (1970-2007) for the two countries (Argentina and Brazil).

Each model – the one with import penetration and the other with trade openness - is divided into five progressively more detailed steps:

- model (1) considers the sample of two countries as the baseline;
- model (2) interacts the value of import penetration/trade openness of the baseline with the macro-sector;
- models (3) and (4) take the baseline and interacts it with one country (Brazil) in order to check whether there are significant differences between the two countries. The results are shown separately for Brazil model (3) and Argentina model (4);
- model (5) takes model (2) and runs it separately for each country: model (5) and (6) display the results for Brazil and Argentina respectively.

We specify the following equation[30]:

$$\log wagegap_{it} = \beta_0 + \beta_1 \log prod_{it-1} + \beta_2 \log marg_{it-1} + \beta_3 \delta \log imp_{it-1} + \beta_4 \log wagegap_{t-1} + a_i + u_{it} \quad (5)$$

where log $wagegeap_{it}$ is the dependent variable measured as the log ratio between average wage in sector *i* at time *t* and median wage of the macro-sector, $prod$ is the productivity, $marg$ is the gross margin, imp is the import (all independent variables are expressed in logs and at time t-1) and $a_i$represents the fixed effect. The second model replaces the index of import penetration with that of trade openness $(tradeop)$ holding every other aspect constant.

3.6.1. Hypotheses

Chapter 2 of this thesis concluded that the Argentine industrial specialization, contrary to the Brazilian one, is deeply rooted in NR intensive industries - proved by their capacity to trigger structural change along with their top highest value added. In Brazil the industrial specialization shows a relatively higher dynamism of R&D intensive industries, which are also the main triggers for structural change. This chapter takes these findings one-step further. Firstly, by tackling which indicators of structural change most significantly contribute in explaining sectoral wage gaps (H1, H2, H3 and H4) (first column of Table 3.2.). Secondly, by breaking down such effect at a macro-sectoral level (H5) (second column of Table 3.2.). To this end, the coefficients of trade openness and import penetration are interacted with the macro-sectors - NR, R&D and LI industries. This will shed light as to

[30] The same model has been performed with a variation of the dependent variable given by the average wage per worker divided by the mean instead of the median by macro-sectors and the results are significantly similar. Nevertheless the median, as opposed to the mean, better represents the wage per worker by macro-sector given the much skewed wage distribution (see Graph B.6. in Appendix B) motivating the use of the median in our models which is also in line with the relevant literature (Mahler *et al.*, 1999, and Thewissen *et al.*, 2013).

whether certain macro-sectors, which are more exposed to structural change, are also likely to pay higher wage *premiums* with respect to others. The hypothesis, formulated on the basis of the empirical and theoretical frameworks combined with the study of the descriptive statistics shown in Appendix B – Tables B.1.1. -.5 - is structured as follows:

H1. A rise in *productivity* should to induce higher wage gaps in both countries. This is because, according to the Walrasian theory of labour market, in absence of any market frictions workers earn a wage rate that is equal to their marginal productivity. In fact, when wages are under the productivity level, sectors have an incentive to hire more workers, inducing an upward pressure on wages. Conversely, when wages are above the marginal product, sectors tend to reduce their employment and wages (Cashell, 2004). Hence it follows that the trend in productivity should be directly and positively correlated with the trend in wages. Since productivity is highly heterogeneous among sectors, all else being equal, a rise in productivity should be reflected in the concomitant wage heterogeneity, hence inducing a higher cross-sectoral wage inequality.

H2. *Trade openness* should increase the rents of industries engaged in exports and this in turn should raise wages. Since the wages are highly heterogeneously distributed across sectors, all else being equal, this should increase wage gaps because exports provide room for higher profits and hence earnings (Baumgarten, 2010, Schank *et al.*, 2007 and Mahler *et al*., 1999).[31]

H3. An increase in *import penetration* should lower the rents of industries producing durable goods and might impair the wages and employment possibilities due to the competition with foreign firms or sectors (Borjas and Ramey 1995, Mahler *et al*., 1999). This should lower wages and, other factors being equal, reduce sectoral wage gaps (Mahler, 1999).[32]

H4. Total income distribution is the result of the allocation of revenues over production between profits, which in our model are represented by *gross margin*, and wages (PADI, Katz and Stumpo, 2001). Depending on the structure of the

[31] Bernanrd and Jensen (1995) and Schank *et al*., (2007) maintain that higher wage gap can affect total wage dispersion through two channels. First, the amount of workers employed in exporting sectors might change, for example due to increasing exports sectors relative to non-exporting sectors. Second, the size of wage differential might change due to the fact that for example exporting sectors benefit most from the globalization, leading them to share part of the additional gains with their workers.

[32] Borjas and Ramey (1995) take this assumption one step further by arguing that an increase in imports should decline the wage of relatively less educated workers. This because durable goods industries employ a disproportionate share of less educated workers, they are featured by highly concentrated rents and share those rents by paying higher-than average wages. The subdivision of low or high skilled workers is unfortunately not made possible with the PADI.

distribution between profits and wages which also should be sector-specific, in principle we predict that the higher is the share of revenues going to profits (or gross margin), the lower is the share of rents benefiting wages and *ceteris paribus* wage gaps.

H5. NR intensive industries. In these sectors an expansion in import penetration should negatively impact and impair employment and wages of domestic production, which *ceteris paribus* should decrease wage gaps. We hypothesize that within NR industries the imported goods are likely to replace domestic workers' production. Trade openness, similarly to import penetration, should negatively affect wage gaps. The benefits of higher revenues *via* higher exports in highly capital intensive sectors such as the NR intensive industries, is more likely to be reverted to capital investments rather than to workers' wages and *ceteris paribus* wage gaps.

LI intensive industries. In these industries featured by a high degree of labour, import penetration is likely to diminish wages and wage *premiums*. Imports - especially considering the competition from East Asiatic Tigers and their marked specialization in labour intensive industries - are likely to substitute locally produced durable goods.[33] Conversely, trade openness should provide more space for domestic production, inducing a higher demand of labour, hence increasing wages and, all else being equal, sectoral wage *premiums*.

R&D intensive industries. We predict that import penetration should induce higher wage *premiums*. The assumption behind is that imports within this macro-sector are likely to be complementary, and not a substitute - as in the case of NR and LI industries - of the local production, leading to an increase in sectoral wage gaps. Trade openness, similarly to the other two macro-sectors, should increase wage gaps by expanding domestic production in a macro-sector that tends to be more dynamic and presumably employing relatively higher skilled workers (hence perceiving higher wages).

[33] There is much evidence showing that for Brazil for instance the competition from trade liberalization largely downplayed the domestic production of LI intensive sectors such as those of footwear or textiles (Cimoli and Katz, 2003). This occurred because fierce competition of East Asiatic tigers were producing the same type of goods but at much cheaper price. At the same time the high economic growth of the East Asiatic tigers needed and still need to be fuelled with large endowment of natural resources, of which Brazil and Argentina are both largely endowed and that in fact is the main candidate in explaining the commodity boom experienced by the two countries during the middle of the 2000s.

Table 3.2.

Summary of the hypothesis on factors affecting sectoral wage *premiums*				
Causes of sectoral wage *premiums*	**Overall effect on wage gaps**	**Effect at the macro-sectoral level on sectoral wage gaps**		
Import penetration	-	NR -	LI -	R&D +
Trade openness	+	NR -	LI +	R&D +
Productivity	+			
Gross margin	-			

Source: author's elaboration based on the hypothesis section.

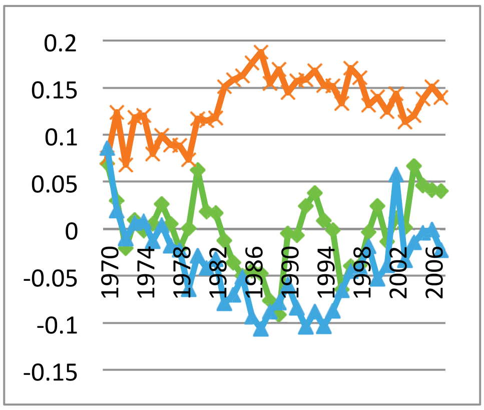
3.7. Results

3.7.1. Sectoral wage gap by macro-sector and country

The first building block of our analysis is founded on the evolution of cross-sectoral wage inequality, represented by the average for each macro-sector of the log ratio between the sectoral average wage per worker and its median by macro-sector adapted from (Mahler *et al*, 1999) as illustrated in Graphs 3.5. and 3.6.

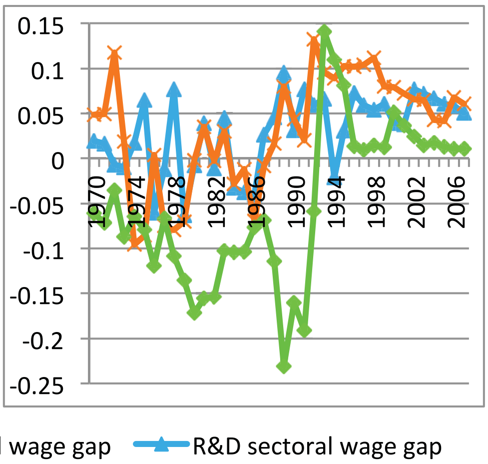
Graph 3.5.

Evolution of sectoral wage gap by macro-sector Brazil



Graph 3.6.

Evolution of sectoral wage gap by macro-sector Argentina



Of particular note in these two graphs is the dramatic volatility and wage dispersion of NR and LI intensive industries within both countries, a trend that is common to R&D intensive industries in Argentina but less so in Brazil.

If we look at the Brazilian case more closely (Graph 3.5.), regardless of similar levels in average wage per worker in the R&D and NR intensive industries, the latter accounts for much higher wage gaps, with extremely highly- and lowly-paid sectors coexisting in the same macro-sector. For instance, in 2007, the oil sector's average wage was about 12 times higher than that of the coal industry. R&D intensive industries in turn, not only pay overall amongst the highest wage per worker, but such wages appear to be more homogenously distributed as compared to the LI and NR intensive groups. In the R&D industries, the highest paid sector is that of transport and equipment whose wages are just about double than those in the least paid sector of metal and equipment. The crucial contribution of R&D industries towards structural change, found in *Chapter 2* of this thesis, not only goes along with a lower cross-sectoral inequality within this macro-sector, but also with average wages per worker that are almost as high as the NR intensive industries. Presumably, the more equal capital and technological penetration in the R&D group is reflected in a more uniform distribution of sectoral wages.

The overall evolution of sectoral wage gaps in Argentina (Graph 3.6.) is noticeably much more volatile than in Brazil. The highest level of wage gap pertains to NR intensive industries but, contrary to Brazil, R&D and LI industries are featured by similar and at times overlapping trends and appear to be less subjected to the volatility affecting the NR group. In 1988 average wages in the oil sector were more than ten times higher than the least paid sector in NR, non-ferrous metal. Conversely, average wages per worker are more equally distributed in the R&D intensive group. For the same year under consideration, 1988, the top-paid sector in R&D, electrical machinery, was just about three times higher than the least paid sector, metal product. In Argentina, average wage per worker is the highest in NR industries (Graph 3.2.) which are also the ones featured by the most volatile and higher cross-sectoral wage dispersion. Considering that these industries are also those with a higher value added and output, it follows that if Argentina continues to invest resources in this macro-sector, cross-sectoral wage gaps are likely increase.

3.7.2. Panel regression with import penetration

The second building block of the study unravels the impact of structural change on sectoral wage *premium* focusing on import penetration through fours progressively more detailed steps (Table 3.3.).[34] The estimated coefficients from the four models are consistent, underlying the robustness of the estimated results.

The first baseline model (1) includes the overall sample (both countries jointly considered). As expected in our hypothesis (H1) an increase in productivity is associated with a rise in sectoral wage *premium*. More specifically when productivity grows by 1%, sectoral wage gaps increase by 0.048%. The coefficient of the first lagged value of the dependent variable is highly positive and strongly affects the dependent variable itself. An increase by 1% in the value of the deviation of wage per worker in the previous year increases the wage gap by 0.7% in the current year. In turn, an increase by 1% in the gross margin (H4) is associated with a decrease of sectoral wage *premium* by 0.021%. Import penetration has a negative impact on sectoral wage gaps (H3): they diminish by 0.00012% when the import penetration index raises by 1%. These results corroborate much of the reviewed literature stressing the substantial disruption induced by trade liberalization and especially by the massive inflow of imports, particularly in the technology intensive sectors for both countries (Cimoli and Katz, 2003; Novick and Tomada, 2007 and Cimoli *et al.*, 2014). However, the coefficient for import penetration is quite low and it will be interesting to further discern its effect at the country and macro-sectoral level.

When disentangling the effect of import penetration for the overall sample (Argentina and Brazil jointly considered) and by macro-sector (model (2)) some interesting differences arise. Consistent with our hypothesis (H5), results suggest that the positive impact of import penetration is intensified by R&D and LI industries, while the opposite occurs in the NR intensive group. More specifically an increase by 1% in import penetration in NR intensive industries is associated to a decrease in wage gaps by 0.043%. This is most probably due to the fact that in NR intensive industries imports can substitute domestic production, with a downward pressure on wages and, all else equal, on wage gaps. By contrast, within R&D and LI intensive industries an increase in import penetration by 1% is associated with a rise in wage gaps by 1.8% and 2.11% respectively (though the significance level for the LI group is at 10%). This result might be explained by the fact that in R&D and LI intensive industries import penetration can be complementary and supportive of the domestic production, pushing wage

[34] We used the Hausman test (see Appendix B.3.) to determine whether the random effect estimator is appropriate for the estimation both with import penetration and trade openness. In all specifications the validity of the random-effect estimator is rejected. Hence we report the results for the fixed-effect estimation which allows controlling for omitted variables that differ between cases but are constant over time (or time invariant characteristics) which can include factors such as production intensities and firms 'business practices.

premiums upwards. The signs of the remaining covariates –productivity and gross margin – are consistent with the previous models and the HP1 and 4.

Model (3) [35] includes in the baseline model (1) an interaction dummy for each of the independent variables for Brazil, in order to capture whether there are significant differences between the two countries. The results are divided into two parts: the first displays the coefficients for Brazil (3) whereas the second for Argentina (4). Productivity positively affects sectoral wage *premiums* in both countries though the effect is more pronounced for Brazil. Here in fact an increase by 1% in productivity is associated with a growth in wage gaps by 0.07%. On the contrary, in Argentina, an increase by 1% in productivity is associated with a rise in sectoral wage gaps by 0.03%. Both in Brazil and Argentina a rise by 1% in the gross margin leads to a decline in sectoral wage *premium* by 0.037% and 0.0158% respectively. The coefficient of import penetration is unfortunately not significant for Argentina. In turn, in Brazil an increase of 1% in import penetration exerts a mild negative impact on sectoral wage gaps, which decline by 0.000127%. This result might be explained by the fact that, considering all the industries together, import penetration can act as a substitute of domestic production, with a downward pressure on wages and, *ceteris paribus*, on wage *premiums*. Finally, both in Argentina and Brazil the lagged value of the dependent variable is positively related to sectoral wage gaps. More specifically an increase of 1% in the lagged value of the log deviation of wages per workers increases the overall wage gap by 0.78% and 0.71% in Argentina and Brazil respectively.

Model (5) [36] approaches the two countries separately disentangling import

[35] In model (3), each covariate is interacted with a dummy for one country, Brazil (Bra) and only the aggregated coefficients are displayed for both countries (see output table below model 3 and 4). In a second version (see Table B.4.1. in Appendix B.4.) the non-interacted and the interacted effects are separately displayed. Both approaches are conceptually correct and lead to the same coefficients. Yet, while the former provides the effects already summed up and separated for the two countries, the latter version requires the summation of the coefficients (of the variable term and its interaction) for Brazil in order to see the total effect of the covariates for this country. Additionally the latter model allows observing whether the coefficients are significantly different between the two countries

[36] The number of observations (or sectors) in Brazil is smaller than in the Argentine case (model (5) with 999 *vs* model (6) with 1014 observations respectively). This occurred since the value of gross margin in Brazil for the pottery industry is negative, and the log value of a negative number results as a missing value which ultimately led to a relatively smaller number of observations for the Brazilian case. Besides, pottery relative importance on the whole manufacturing sector is low or negligible. Its productivity level and added value are amongst the lowest throughout the whole period (*i.e*. in 2005 pottery's productivity was about 820 times lower than the most productive sector, coal. Likewise pottery's value added in 2005 was about 800 times lower than food, the sector with the highest value added).

penetration's effect at a macro-sectoral level.[37] Results indicate that in Brazil (model (5)) the positive impact of import penetration on wage gaps is magnified by the R&D macro-sector, while the reverse occurs in the NR macro-sector. More specifically, an increase by 1% in the level of import penetration rises by 5.9% and diminishes by 0.13% the level of wage gaps of the R&D and NR intensive industries. The result is unfortunately not significant for the LI macro-sector. Both productivity and gross margin maintains the same signs as in the previous models, highlighting the robustness of the obtained results. Consistent with our hypothesis, the results suggest that imports within R&D industries might not be substitutable but complementary to the production of more technological intensive goods, which might increase overall production and, all else equal, wage *premiums*. Hence in Brazil the dynamism of R&D industries is twofold. Firstly, they pay among the highest average wages, which are also homogenously distributed across the macro-sector. In fact R&D industries tend to be characterized by a relatively more homogeneous capital and technological penetration, directly reflecting a more uniform average wages distribution. Secondly, R&D sectors demonstrated the capacity to generate higher wage *premiums via* import penetration, underlining the positive impact of structural change on wage *premiums*.

There is no evidence of a significant impact of import penetration at a macro-sectoral level on wage gaps in Argentina, separately considered (model (6)). The only significant coefficients are the non-interacted by macro-sector ones, including the lagged value of the dependent variable, productivity and gross margin, which display the expected signs.

[37] The output table also presents the results for Argentina (model (6)), despite the fact that the interaction of import penetration with the macro-sectoral dummy is insignificant. The remaining coefficients confirm the results obtained from the previous models.

Table 3.3.

Model with import penetration

Dependent Variable Wage gap	**Base model overall sample (1)**	**Base model with import penetration interacted with macrosector (2)**	**Base model with interaction by country. (Brazil) (3)**	**Base model with interaction by country (Argentina) (4)**	**Model (2) for Brazil (5)**	**Model (2) for Argentina (6)**
Productivity t-1	0.048 (0.048) ***	0.0627** (0.123)	0.0741 (0.016) ***	0.0361 (0.0121)**	0.0832 (0.0176)***	0.040 (0.0161)**
Gross margin t-1	-0.214 (0.01) ***	-0.0280** (0.007)	- 0.0376 (0.0131)***	-0.0158 (0.0072)**	-0.0436 (0.0135)**	-0.0204 (0.0088)**
Import penetration t-1	-0.00012 (0.006) ***		-0.0001 (0.0003)***	0.0027 (0.0003)		
Wage gap t-1	0.075 (0.0155) ***	0.6035** (0.0186)	0.7158 (0.0260) ***	0.780 (0.0193)***	0.7169 (0.0238)***	0.7756 (0.0563)***
Import penetration by Macro-sector t-1: NR	NR	-0.0004 (0.00) ***			-0.0001 (0.0001) ***	-0.06604 (0.0563)
Import penetration by Macro-sector t-1: LI	LI	0.0212 (0.012) *			0.048 (0.0719)	0.14122 (0.0554)
Import penetration by Macro-sector t-1: R&D	R&D	0.0187 (0.007) ***			0.059 (0.236)**	0.1989 (0.0563)
Observations	2013	2013	2013	2013	999	1014

Notes: Panel regression, sector level fixed effects. All explanatory variables are taken in their lagged value at year t-1 with respect to the dependent variable which is considered in year t. Sectoral wage gap, productivity and gross margin are taken at their logarithmic values. z statistics with robust standard errors adjusted by clustering at 3-digit ISIC industries in parentheses. *Significant at 10%, **Significant at 5%, ***Significant at 1%.

3.7.3. Panel regression with trade openness

The second model determines the impact of structural change on sectoral wage *premium* focusing on the second critical factor representing structural change: trade openness. Similar to the previous section, Table 3.4. displays the results for the six models, progressively augmenting the detail of the analysis.

Overall the signs of the selected covariates are consistent throughout the six models, indicating the robustness of the model itself. [38]

Consider the first results of the baseline model for the two countries (model (1)). Cross-sectoral wage inequality appears to be responsive to productivity and gross margin, with the expected signs. Increase in productivity is likely to push cross-sectoral wage inequality upwards, while a growth in the gross margin - the share of revenues going to profits rather than wages – seems to have a negative effect on wage *premiums*. Trade openness appears to have a negative impact on sectoral wage gaps: they diminish by 0.0001% when the openness coefficient raises by 1%. This result contradicts our predictions, according to which an increase in trade openness should have provided more room for local production, increasing revenues, wages and wage gaps. Such a negative sign might be related to trade liberalization's detrimental effect on workers, particularly of those with scant labour mobility and whose skills were not easily transferable. The literature in this regard maintains that openness forced firms into ruthless completion, jeopardizing wages and job security which probably translated into lower sectoral wage *premiums* (Novick and Tomada, 2007). The coefficient of trade openness though is quite low and it will be interesting to further disentangle its effect at the country and macro-sectoral level.

When discerning the effect of trade openness by macro-sector for overall sample ((2) model) some significant differences between the three macro-sectors emerge. Consistent with our hypotheses, results strongly suggest that the positive impact of trade openness on sectoral wage gaps is amplified by R&D and LI industries, whereas the reverse holds true for NR intensive industries. These results reveal that the nature of the macro-sector matters in explaining the different impact of structural change on wage gaps. In principle, trade exposure should provide industrial sectors with higher potential of production, job creation, higher earnings, and, all else being equal, higher wage gaps (Mahler *et al*., 1999). This channel of causation works quite effectively in LI and R&D intensive sectors, which

[38] Additionally the common independent variables of the current model with trade openness, and the previous one with import penetration - productivity, gross margin and the lagged value of sectoral wage gaps - also display the same sign.

tend to boast dynamic comparative advantages. In contrast, in such highly centralized and capital-intensive sectors as the NR intensive ones – featured by low domestic knowledge and static comparative advantages – there is no evidence of the beneficial effect of structural change on wage gaps. To be more precise, the impact of structural change in NR industries on wage *premiums* appears to be downplayed by dynamics strictly bound to the mere 'natural' comparative advantage of the economy, suggesting that within this macro-sector structural change does not directly translate into higher sectoral wage gaps.

Model (3) interacts the independent variables of the baseline model (1) with Brazil, in order to capture whether there are significant differences between the two countries. The results are split into two parts: the first one displays the coefficients for Brazil (3), the second for Argentina (4).

Consistent with our hypothesis, productivity is positively associated with sectoral wage *premiums* in both countries, thought the effect is more accentuated in Brazil. Here in fact an increase by 1% in productivity goes along with a rise in wage gaps by 0.07%. In turn in Argentina, an increase by 1% in productivity is associated with increases sectoral wage gaps by 0.03%. The lagged value of the dependent variable appears to affect strongly and positively sectoral wage gaps, while a rise in gross margin is negatively related to wage *premiums*. The coefficient of trade openness is unfortunately not significant for Argentina. In turn, in Brazil an increase by 1% of trade openness is associated with an overall decrease in sectoral wage *premium* by 0.00011%, a result that refutes our predictions. Most probably, considering all the industries together, an increase in openness might not directly translate into higher sectoral wage gaps due to their different structural composition and rent redistribution, motivating a further investigation of its effect at a macro-sectoral level.

Model (5) unravels the effect of trade openness at a macro-sectoral level separately for each country.[39] In Brazil sizable differences at macro-sectoral level arise and the results are much in line with those previously discussed in paragraph 3.7.2. R&D intensive industries have the potential to catalyse the positive effect of trade openness on wage gaps, while the opposite holds true for NR intensive industries. The coefficient for LI industries is unfortunately not significant. This evidences that the high technological nature of R&D industries generating more productive and better jobs (Cimoli *et al.*, 2014) is likely to facilitate the positive transmission mechanism between trade openness and higher wage *premiums*.

[39] We also displayed the results for Argentina (model (6)), regardless of the fact that the interaction of trade openness with the macro-sectoral dummy is insignificant. The remaining coefficients confirm the results obtained from the previous models.

In contrast, NR industries, wherein workers tend to be less protected and have a low bargaining power, as the production is inherently capital – rather than skill - intensive, structural change *via* trade openness appears to have a negative impact on wage gaps. Unfortunately the coefficient for labour intensive industries is not significant.

These results are interesting in their own rights, given that the generalized perception is that cross-sectoral wage inequality is largely explained by supply side related causes which do not even address the issue of inequality from a sectoral perspective. We have understood that from a macro-economic point of view the nature of the industrial sector can act as a platform to improve the positive association of structural change on sectoral wage *premiums* and that such effect is magnified by more dynamic sectors like the technological and R&D intensive ones.

We found no evidence of significant impact of structural change *via* trade openness on wage *premiums* in Argentina at a macro-sectoral level separately considered (model (6)).

Table 3.4.

Model with trade openness

Dependent Variable Wage gap	**Base model overall sample (1)**	**Base model with trade openness interacted with macrosector (2)**	**Base model with interaction by country. (Brazil) (3)**	**Base model with interaction by country. (Argentina) (4)**	**Model (2) for Brazil (5)**	**Model (2) for Argentina (6)**
Productivity t-1	0.0489 (0.0099) ***	0.066521 (0.01250) ***	0.07434 (0.0169) ***	0.03611 (0.0121)**	0.0820 (0.0174)***	0.0401 (0.0162)**
Gross margin t-1	-0.02153 (0.02153) ***	-0.02944 (0.00718)**	- 0.0378 (0.0131)**	-0.0157 (0.0072)**	-0.0428 (-0.0427)**	-0.0200 (0.0090)**
Trade openness t-1	-0.000117 (0.0001) ***		- 0.0001 (0.0001)***	0.001978 (0.0031)		
Wage gap	0.7549 (0.0155) ***	0.6035** (0.0186)	0.7804 (0.0260) ***	0.780457 (0.0193)***	-0.7159 (0.0237)***	0.7766 (0.0214)***
Trade openness by Macro-sector t-1	NR	-0.0004 (0.0006) ***			- 0.0001 (0.0000) ***	-0.0404 (0.3683)
	LI	-0.0226 (0.0106) **			0.0121 (0.0201)	0.0866 (0.0357)
	R&D	0.01692 (0.0069) **			0.0439 (0.0187)**	0.0809 (0.0359)
Observations	2013	2013	2013	2013	999	1014

N*otes*: Panel regression, sector level fixed effects. All explanatory variables are taken in their lagged value at year t-1 with respect to the dependent variable which is considered in year t. Sectoral wage gap, productivity and gross margin are taken at their logarithmic values. z statistics with robust standard errors adjusted by clustering at 3-digit ISIC industries in parentheses. *Significant at 10%, **Significant at 5%, ***Significant at 1%.

3.8. Conclusions

There are different views on the effect of structural change on wage inequality which is putting pressure on governments wanting to enhance competitiveness by raising wages of the most productive sectors, while promoting an equitable wage distribution across them (Cornia *et al.*, 2014, Wood, 1997 for Latin America and Thewissen *et al*., 2013 and Mahler *et al.*, 1999 for developed countries). The empirical evidence, however, fails to properly acknowledge the importance of inter-sectoral wage inequality in developing countries like Brazil and Argentina that experienced a profound process of structural reforms and economic liberalization, albeit with slightly different timing.

Our approach, linking the evolutionary and the labour market literatures, stresses the *sectoral* dimension of the impact of structural change on cross-sectoral wage inequality. There is no reason whatsoever to believe that sectors will behave equally in response to structural change since they do not only differ in the goods and services they produce, but also in their capacity and timing to react to changes. In our work, such sectoral focus is facilitated by the possibility of grouping the PADI database, covering 28 manufacturing sectors, into three main "macro-sectors": NR, LI and R&D intensive industries.

While several empirical papers have extensively explored the relationship between structural change and the "within" sectors inequality, to the best of our knowledge there has been no attempt to examine the effect of structural change on the "between" sectors inequality, which we believe is key when adopting a macro-economic perspective. As a complement to these studies, this paper examines if and to what extent workers can benefit from wage *premiums* by way of productivity, gross margin and trade dynamics – identified as channels of structural change - and whether these effects are significantly different depending on the macro-sector in which the worker is employed.

RQ1 accounts for the trend of cross-sectoral wage inequality which we have found to be much more volatile and at times overlapping – especially in the case of R&D and LI industries - in Argentina than in Brazil. Specifically, in Brazil the level of inequality is the lowest in R&D industries. Most likely R&D sectors are featured by a more uniform capital and technological penetration (Holland and Porcile, 2005), which should reflect into a more uniform distribution of wages per worker within these industries (since, in principle, wages should follow productivity). NR industries in both countries display the second most unequal level of inequality - though in Argentina at times it overlaps with the inequality level of R&D industries. The highly differentiated profitability of NR intensive industries (*ibid*) is reflected by the presence of high-paid/high-productivity sectors, like oil, with low-paid/low-productivity sectors, like wood products. LI industries in both countries display among the highest level of wage gap, evidencing a sizeable deviation of the mean wage in LI intensive sectors from the median of that macro-sector.

The paper proceeds by empirically investigating which channels of structural change - among productivity, gross margin, import penetration and trade openness - most prominently contribute to the generation of cross-sectoral wage *premiums* (RQ2). Subsequently it estimates whether the structural change effect is macro-sectoral-specific (RQ3). Our prediction that the nature of the macro-sector matters in explaining the different impact of structural change on wage gaps has been corroborated by the empirical analysis.

Results strongly suggest that for the overall sample and Brazil separately considered, when both trade openness and import penetration loom large in R&D intensive sectors, domestic production benefits from it and so do wage *premiums*. In fact, these sectors and the relatively more skilled workers they employ, tend to respond more flexibly to crises or demand shocks. Hence, R&D industries appear to act as a springboard between structural change and higher wage gaps, both through trade openness, by providing more room for higher production and hence higher wage *premiums*, and through import penetration, presumably because imports within these industries are likely to act as a complement of the local manufacture.

In contrast, the effect of trade openness and import penetration in NR intensive industries is associated to a reduction in wage gaps. These industries tend to be highly centralized, capital intensive and dismissive of domestic knowledge generation (Cimoli and Katz, 2003). These factors certainly constrain the positive transmission mechanism between structural change, *via* trade dynamics, and high wage *premiums*. This supports our assumption (H5) that import penetration within the NR intensive macro-sector acts as replacement –and not as a complement, as for the R&D group- of the domestic production, with a detrimental impact on wages and *ceteris paribus* wage gaps. Similarly, openness drastically impacted the performance of LI sectors which, by adopting a defensive and opportunistic behaviour (*ibid*), jeopardized wages and wage gaps.

For both countries jointly and separately considered a rise in productivity is associated with higher wage gaps, though the effect is more evident in Brazil. Conversely, gross margin, representing the gross profit of enterprises, negatively affects sectoral wage gaps. The first lagged value of the dependent variable is always positive and high for both countries indicating that much of the level of the cross-sectoral wage gap in year t is explained by the level of wage gap in year t-1.

The fact that the separate model for Argentina did not provide significant results - with exception to the lagged value of the dependent variable itself - suggests that in Argentina, unlike Brazil, structural-change related factors did not significantly contribute to the generation of higher wage *premiums*.

The following policy implications emerge from this analysis. Even though in Brazil and Argentina there are two different engines for structural change – R&D intensive industries and NR intensive industries respectively - through this paper we found that only the former act as a vehicle for higher sectoral wage *premiums.* This would imply workers would on average benefit from higher wages, when structural change acts in the most R&D and technological intensive sectors. Furthermore, sectoral wages across this macro-sector are more equally distributed than the other two macro-sectors (NR and LI industries).

Hence, if increased trade openness and import penetration in R&D intensive industries go along with higher wage gaps, and if sectoral wages are more equally distributed within this macro-sector, efforts to shift resources from traditional NR industries towards more technological intensive ones are of foremost importance. These efforts might include for example, encouraging the development of competences on differential technological skills, assets and organizational routines that ultimately provide the platform for a sector's ability to be competitive over time (Nelson and Winter, 1982). Pre-existing capabilities which are unevenly distributed across industrial sectors are central to ease the adjustment process of wage distribution across sectors. Such capabilities, as well as a strategic shift towards more technological intensive industries, can be geared and fostered through targeted foresight policies which will be addressed in *Chapter 4* of this thesis.

Finally it is important to point to the limitation of this analysis as well as to the lines for future research. First, given the lack of data at a worker level within each industry, it is not possible to test the effect of structural change on different occupational categories, and hence to understand the drivers of the "within" sector wage inequality. More disaggregated data would increment the detail of analysis and enable testing SBTC and trade related causes of wage inequality in a more detailed manner. Data at the occupational level are available for each country, but they usually come at the expense of spanning over a shorter time frame which is not congenial to examine the impact of structural change. More disaggregated data would also come at the expense of a reduced possibility to undertake cross-country comparison, as each country has its own definition and conformation of “occupational category”. A second shortcoming of this study lies in the macro-sectoral classification (PADI, Katz and Stumpo, 2001) as the separation between NR, LI and R&D can oversimplify the complex nature of industrial sectors. The nature of industries changes, along with technological revolutions. NR industries do not necessarily exclude R&D content in their specification, as in some sectors NR and R&D coexist. For instance, if we consider the role of technology in the Argentinian soybean or the Brazilian biofuels industries, it is evident that NR resources are far from being a coarse from which it was crucial to keep back. They to some extent prove to be highly knowledge-intensive sectors. Unfortunately the aggregation of our classification does not account for these sectors specificities. Furthermore, to provide a solution to this problem it would be necessary to build a dynamic classification changing over time and across countries, which to our knowledge is not available. We believe that the costs of simplifying the reality by forcing sectors into specific classifications is, anyway, compensated by the benefit of analysing the industrial sector for such a long period (38 years).

Appendix B

Appendix B.1.
Summary statistics

The five tables below display the descriptive statistics for the variables used in the econometric model: table B.1.1. represents the two countries together; table B.1.2. and B.1.3. display the countries separately considered, and table B.1.4. and B.1.5. show the value of import penetration and trade openness, average wage per worker, and employment by macro-sector for Brazil and Argentina respectively (in table B.1.4. and B.1.5. cells have been highlighted in the colour previously used in the graphs to represent the macro-sector in order to facilitate the numbers' interpretation).

Table B.1.1.

Descriptive statistics overall sample

Variable		Mean	Std. Dev.	Min	Max	Observations
Sectoral wage gap	overall	.0281	.4298	-1.1170	1.9361	N = 2128
	between		.4051	-.8657	1.3928	n = 56
	within		.1533	-.53155	1.0032	T = 38
Productivity	overall	9.6391	1.1369	6.3657	14.4985	N = 2128
	between		1.0783	6.7467	13.1735	n = 56
	within		.3875	8.2944	11.384	T = 38
Gross margin	overall	6.4391	1.5902	-3.9120	9.5575	N = 2068
	between		1.5324	2.2982	8.9677	n = 55
	within		.5500	.22892	8.8229	T=38
Import penetration	overall	8.7053	92.7810	0	2176.469	N = 2128
	between		63.0881	.0049	472.363	n = 56
	within		68.5389	-452.82	1712.81	T = 38
Trade openness	overall	9.5181	100.300	.0001	2263.75	N = 2128
	between		67.8793	.0168	508.385	n = 56
	within		74.3822	-486.29	1764.88	T = 38

Note: Sectoral wage gap, productivity and gross margin are taken at their logarithmic values.

Table B.1.2.

Descriptive statistics Brazil						
Variable		Mean	Std. Dev.	Min	Max	Observations
Sectoral wage gap	overall	.0401	.4555	-1.1170	1.7579	N = 1064
	between		.4445	-.8657	1.3928	n = 28
	within		.1294	-.5195	.96728	T = 38
Productivity	overall	9.5095	1.1809	6.3657	14.4985	N = 1064
	between		1.1560	6.7467	13.1735	n = 28
	within		.32376	8.3103	10.8345	T = 38
Gross margin	overall	7.1912	1.2016	3.8316	9.5575	N = 1026
	between		1.1472	4.6132	8.9677	n = 27
	within		.41888	5.6326	8.2647	T = 38
Import penetration	overall	16.9945	130.7138	0	2176.469	N = 1064
	between		89.2441	.0049	472.3638	n = 28
	within		96.9473	-444.5321	1721.099	T = 38
Trade openness	overall	18.4484	141.309	.0008	2263.75	N = 1064
	between		96.0189	.0338	508.3857	n = 28
	within		105.2117	-477.3657	1773.813	T = 38

Note: Sectoral wage gap, productivity and gross margin are taken at their logarithmic values.

Table B.1.3.

Descriptive statistics Argentina						
Variable		Mean	Std. Dev.	Min	Max	Observations
Sectoral wage gap	overall	.0162	.4024	-.8896	1.9361	N = 1064
	between		.3693	-.5848	1.1238	n = 28
	within		.1740	-.4742	.99124	T = 38
Productivity	overall	9.7688	1.0762	7.4445	13.141	N = 1064
	between		.9986	8.0252	12.342	n = 28
	within		.4424	8.4240	11.514	T = 38
Gross margin	overall	5.6986	1.5790	-3.9120	9.1781	N = 1042
	between		1.4906	2.2982	8.6854	n = 28
	within		.6541	-.5115	8.0824	T = 38
Import penetration	overall	.4161	1.1767	0	10.3348	N = 1064
	between		.7766	.0065	3.4895	n = 28
	within		.8957	-2.9728	7.2614	T = 38
Trade openness	overall	.5878	1.3895	.0001	12.6294	N = 1064
	between		.9047	.01686	4.1133	n = 28
	within		1.0680	-3.3796	9.1038	T = 38

Note: Sectoral wage gap, productivity and gross margin are taken at their logarithmic values.

Table B.1.4.

Import penetration, trade openness, average wage per worker and employment by macro-sector Brazil

Variable		Mean	Std. Dev.	Min	Max	Observations
Import penetration NR	overall	36.4222	190.0913	0	2176.469	N = 494
	between		130.9842	.0049	472.3638	n = 13
	within		142.3569	-425.104	1740.527	T = 38
Import penetration LI	overall	.0750	.1048	.0001	.6429	N = 380
	between		.0598	.0191	.1809	n = 10
	within		.0880	-.1049	.5417	T = 38
Import penetration R&D	overall	.3215	.4509	.0158	3.4965	N = 190
	between		.3274	.0777	.8947	n = 5
	within		.3422	-.397606	2.9233	T = 38
Trade openness NR	overall	39.3573	205.5171	.0027	2263.75	N = 494
	between		140.9255	.1031	2263.75	n = 13
	within		154.4919	-456.456	1794.722	T = 38
Trade openness LI	overall	.2628	.3950	.0008	2.8692	N = 380
	between		.2568	.0338	.8866	n = 10
	within		.3106	-.6095	2.2453	T = 38
Trade openness R&D	overall	.4567	.5323	.0307	4.1282	N = 190
	between		.3528	.1404	1.0573	n = 5
	within		.4280	-.3593	3.5276	T = 38
Wage per worker NR	overall	3883.98	3056.895	807.5984	19939.65	N = 494
	between		2964.14	1373.46	13226.32	n = 13
	within		1103.578	-3249.46	10597.31	T = 38
Wage per worker LI	overall	2272.443	1080.229	676.1428	5516.173	N = 380
	between		1062.904	1339.666	4524.727	n = 10
	within		383.957	583.9458	3405.916	T = 38
Wage per worker R&D	overall	3564.591	956.6768	1207.717	5797.2	N = 190
	between		764.6366	2685.145	4600.517	n = 5
	within		667.0985	1715.897	4761.274	T = 38
Employment NR	overall	162937.1	223474.2	69	1361344	N = 494
	between		223769.9	217.7105	865777.4	n = 13
	within		60214.36	-204538	658503.6	T = 38
Employment LI	overall	235557.7	165526.3	27752	932135	N = 380
	between		152079.5	62396.24	558210.1	n = 10
	within		80800.07	-100447	609482.7	T = 38
Employment R&D	overall	289346.9	146683.6	18560	584399	N = 190
	between		145618.8	51800.84	429838.9	n = 5
	within		66801.56	23177.04	460679.8	T = 38

Table B.1.5.

Import penetration, trade openness, average wage per worker and employment by macro-sector Argentina

Variable		Mean	Std. Dev.	Min	Max	Observations
Import penetration NR	overall	.1191	.1432	.0001	.7266	N = 494
	between		.1001	.0065	.3790	n = 13
	within		.1061	-.1861	.5405	T = 38
Import penetration LI	overall	.3889	1.033	0	7.5815	N = 380
	between		.6899	.0709	2.3374	n = 10
	within		.7992	-1.9133	5.6331	T = 38
Import penetration R&D	overall	1.242571	2.1617	.0122	10.3348	N = 190
	between		1.3522	.1507	3.4895	n = 5
	within		1.7896	-2.1463	8.0878	T = 38
Trade openness NR	overall	.2072	.2168	.0007	1.3884	N = 494
	between		.1249	.0168	.51764	n = 13
	within		.1804	-.2229	1.2971	T = 38
Trade openness LI	overall	.6331	1.2395	.0001	8.7197	N = 380
	between		.82033	.1545	2.7441	n = 10
	within		.9639	-2.0669	6.6086	T = 38
Trade openness R&D	overall	1.4868	2.541744	.01475	12.629	N = 190
	between		1.574303	.19520	4.1133	n = 5
	within		2.113582	-2.4806	10.002	T = 38
Wage per worker NR	overall	4968.937	3296.042	1369.187	1369.187	N = 494
	between		2894.746	2475.086	13852.77	n = 13
	within		1764.434	-493.257	22874.05	T = 38
Wage per worker LI	overall	3055.309	1293.803	1274.931	7127.274	N = 380
	between		1147.148	1782.077	5459.56	n = 10
	within		697.4585	890.9841	6827.856	T = 38
Wage per worker R&D	overall	3876.349	1166.519	1771.663	7332.671	N = 190
	between		934.8534	2265.363	4596.509	n = 5
	within		811.1141	2511.627	7179.953	T = 38
Employment NR	overall	38993.4	61737.91	122	297491	N = 494
	between		63408.99	230.4211	242932.9	n = 13
	within		9624.193	-2088.54	93551.45	T = 38
Employment LI	overall	46704.24	39690.5	2649	199446	N = 380
	between		31598.19	5465.132	101725.5	n = 10
	within		25968.52	-13800.2	144424.7	T = 38
Employment R&D	overall	64180.56	44655.92	4883	176506	N = 190
	between		36227.66	8314.474	96006.58	n = 5
	within		30637.25	12796.98	155346.1	T = 38

Appendix B.2.
Correlation matrix of the variables included in the model, Brazil
Table B.2.1.

	Sectoral wage gap	Log Productivity t-1	Log gross margin t-1	Trade openness t-1	Import penetration t-1
Sectoral wage gap	1				
Log productivity t-1	0.3215	1			
Log gross margin t-1	0.3829	0.1364	1		
Trade openness t-1	-0.1359	0.4733	- 0.2629	1	
Import penetration t-1	-0.1350	0.4740	- 0.2638	0.999	1

Correlation matrix of the variables included in the model, Argentina
Table B.2.2.

	Sectoral wage gap	Log Productivity t-1	Log gross margin t-1	Trade openness t-1	Import penetration t-1
Sectoral wage gap	1				
Log productivity t-1	0.4359	1			
Log gross margin t-1	0.1152	0.4872	1		
Trade openness t-1	-0.0107	-0.1653	- 0.2473	1	
Import penetration t-1	-0.0238	-0.1600	- 0.2408	0.9754	1

Appendix B.3.
Hausman test implemented in the panel model

The Hausman test has been implemented to determine the validity of the fixed effects over the random effects. Both the models of import penetration and trade openness reject the null hypothesis that the estimated coefficients by the random effect estimator are the same estimated by the fixed effect estimator, implying the superiority of the fixed effect estimation (in both instances the value of Prob>chi=0.000) (see Box B.3.1. and B.3.2.)

Box B.3.1

Value for the computed Hausman: model with import penetration

chi2(40) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 210.86

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)

Box B.3.2.

Value for the computed Hausman: model with trade openness

chi2(40) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 212.22

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)

Appendix B.4.
Interaction term model

This is a separate version of model (3) including each independent variable separately (base model (1)) and interacting it, in addition, with a country-dummy for Brazil, in order to capture whether there are significant differences between the two countries (whereas models 3 and 4 displayed in the text show the net effect for each of the countries).[40]

$$\log\, wagegap_{it} = \\ \beta_0 + \beta_1 \log prod_{it-1} + \beta_2 \log prod_{it-1} * Bra + \\ \beta_3 \log marg_{it-1} + \beta_4 \log marg_{it-1} * Braz + \beta_4\delta\ \log imp_{it-1} + \ \beta_5\delta \log imp_{it-1} * Bra + \\ \beta_6 \log wagegap_{t-1} + \beta_7 a_i \log wagegap_{t-1} * Bra + \ u_{it} \quad (6)$$

This version of the model allows understanding whether the interaction term is significantly different for the two countries. Table B.4.1. displays for each of the covariates two types of outputs: one for the independent non-interacted variable which tells us the coefficient for Argentina; and the interaction term which, summed with the coefficient of the non-interacted variable, provides the coefficient for Brazil. These coefficients precisely correspond to those shown in Tables 3.3. and 3.4. in the main text, where the values are already summed up.

The results are split into 2 parts: columns 1 and 2 (Table B.4.1.) display the coefficients for the model with import penetration and trade openness respectively:

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[40] The previous version of the model showed in the text is specified as follows:

$$\log wagegap_{it} = \alpha + D_i + \beta_1 \log prod_{it-1} * Bra + \ \beta_2 \log marg_{it-1} * Bra + \ \beta_3\delta\ \log imp_{it-1} * Bra + \beta_4 \log wagegap_{t-1} * Bra + \ u_{it}$$

(7). Both versions of the model are consistent (equations (6) and (7)) and lead to the same results.

Table B.4.1.

Base model with import penetration standard interaction term		
	Model (a) with import penetration	**Model (b) with trade openness**
Productivity	0.03617 (0.0121)**	0.03617 (0.0121)**
Productivity* Brazil	0.03789 (0.0204)*	0.0382 (0.0204)*
Gross margin	-0.01581 (0.0072)**	-0.0157 (0.0072)**
Gross margin* Brazil	-0.0218 (0.1530)	-0.0218 (0.1530)
Import penetration	0.00271 (0.0037)	
Trade openness		0.0019 (0.0031)
Import penetration*Brazil	-0.0028 (0.0037)	
Trade openness*Brazil		-0.0020 (0.0031)
Wage gap	0.7802 (0.0193)***	0.7804 (0.0193)***
Wage gap*Brazil	-0.0651 (0.0324)**	-0.0676 (0.0323)**
Observations	2013	2013

N*otes*: Panel regression, sector level fixed effects. All explanatory variables are taken in their lagged value at year t+1 with respect to the dependent variable which is considered in year t. Sectoral wage gap, productivity and gross margin are taken at their logarithmic values. z statistics with robust standard errors adjusted by clustering at 3-digit ISIC industries in parentheses. *Significant at 10%, **Significant at 5%, ***Significant at 1%.

Table B.4.1. illustrates that for both models the effect of productivity on wage gaps in Brazil is significantly different than the effect of productivity on wage gaps in Argentina at 10% level. The impact of gross margin, import penetration and trade openness on wage gaps instead is not significantly different between the two countries. The effect of the lagged wage gap on the wage gap in Brazil is significantly different from the Argentine one at 5% level.[41]

Appendix B.5.
GMM Arellano Bond estimation

In order to further test the robustness of our results we performed the generalized method of moments (GMM) regression results (Arellano Bond, 1991). This method allows to control for the endogeneity of the regressors and the lagged dependent variable that might undermine the efficiency of the panel effect estimation. The model in principle is the same as in equation (5). We treat the lagged values of the dependent variable as endogenous (log wage deviation).

We test for the correctness of the instrumental variable candidate using the Hansen J's test for over-identifying restriction and the validity of the instruments through the Sargan's test. Reassuringly, the tests' results reveal that our instrument is appropriate in all calculations.

Table B.5.1. reports the GMM Arellano Bond estimates analysing the determinants of cross sectoral wage inequality with reference to import penetration. For the base model (1A) it can be appreciated that the results are consistent with panel regression (1), (Table 3.3). An increase by 1% in productivity is associated with an increase in wage gap by 0.09%, while a rise in gross margin by 1% is associated with a decline in wage gap by 0.04%. When breaking down the effect of import penetration by macro-sector it is possible to appreciate a positive effect exerted by import penetration *via* R&D, whereas the value is negative for NR industries. When splitting the overall sample into two countries the base model turns out to be significant only for Brazil (model 2A). The results are consistent with the panel regression in the model (5), (Table 3.3.) whereby an increase in R&D import penetration positively impacts wage gaps, whereas the sign is negative in the NR case. For both GMM models the coefficient for LI industries is unfortunately insignificant.

[41] Table B.4.1.'s interpretation deals with the significant differences between the two countries provided by the "Bra" dummy. The interpretation of each single coefficient has not been included, since it essentially coincides, and therefore would replicate, the discussion provided in section 3.7.2.

Table B.5.1.

Determinants of cross-sectoral wage inequality with import penetration: GMM estimation using Arellano Bond

Dependent Variable: ln (Wage gap)$_{it}$

		Base model overall sample Import penetration interacted with macrosector (1A)	**Model (1A) for Brazil (2A)**
Productivity		0.0903 (0.0494)**	0.1347 (0.057) *
Gross margin		-0.04364* (0.2578)	-0.0621 (0.0431)*
Wage gap		0.0729*** (0.0439)	0.6727 (0.057) ***
Import penetration by Macro-sector	Import penetration NR	-0.0002*** (0.00003)	-0.001 (0.001) ***
	Import penetration LI	0.06871 (0.0444)	0.075 (0.147)
	Import penetrations R&D	0.0212** (0.0092)	0.0079** (0.026)
Sargan test[a] , χ^2 (prob> χ^2)		633.40 (0.12)	605.01 (0.1)
Hansen test prob > χ^2		1.00	1.00
No. of observations		1947	972
AR (1)		0.00	0.003

Note: Robust standard errors in parenthesis. All independent variables are taken at the lagged value. Full set of time and two-digit industry dummies.* Significant at 10%, ** Significant at 5%, *** Significant at 1%. [a] Sargan test of over-identifying restrictions (Null: Instruments are valid). Time dummies are included in all equations.

Table B.5.2. reports the GMM Arellano Bond estimates analysing the determinants of cross-sectoral wage inequality considering trade openness. The base model (1B) as the model (2) corroborates the predictions obtained from the panel analysis in Table 3.4. Model (1) shows that an increase in productivity by 1% is associated with an increase in sectoral wage premium by 0.091%. Gross margin exerts a negative impact on sectoral wage gaps: when it raises by 1% wage gaps diminish by 0.04%. Macro-sectoral divergences arise when disentangling the effect of trade openness. Once again the impact of trade openness on sectoral wage gaps is positive *via* R&D intensive industries and a negative one *via* NR industries.

Model (2B) confirms the results of the panel regression (Tables 3.3. and 3.4.) and indicates that if trade openness rises within R&D industries, this induces positive wage gaps whereas the opposite holds true for the case of NR intensive industries. Unfortunately the coefficient for LI industries is insignificant for both models.

Table B.5.2.

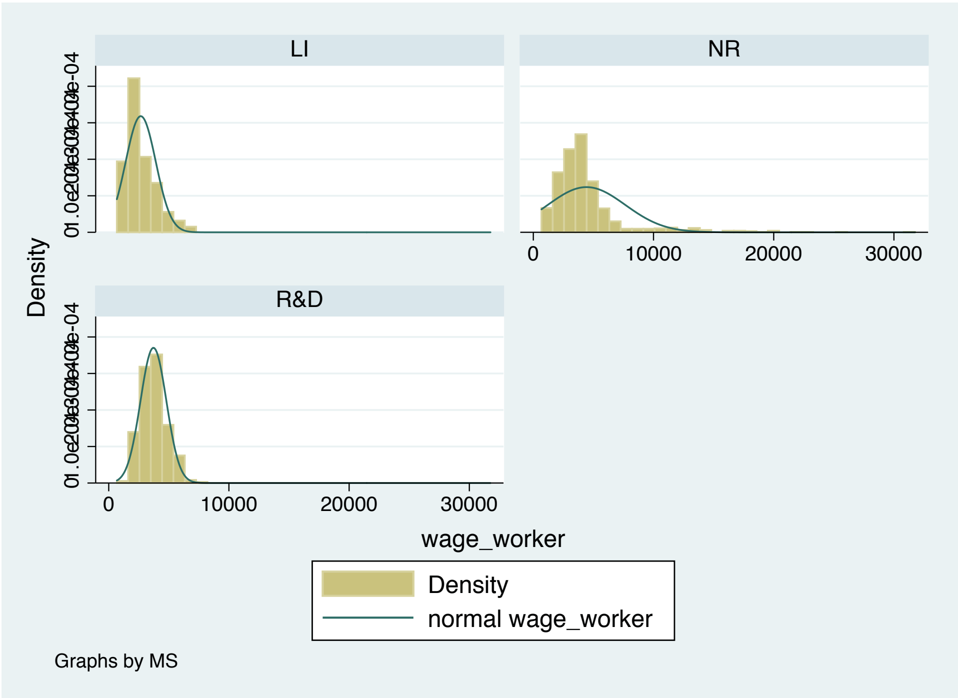
Determinants of cross-sectoral wage inequality with trade openness: GMM estimation using Arellano Bond

Dependent Variable: ln (Wage gap)$_{it}$

		Base model overall sample trade openness interacted with macrosector (1B)	**Model (1B) for Brazil (2B)**
Productivity		0.0910* (0.0476)	0.1328 (0.0773) *
Gross margin		-0.04225 (0.02511)*	-0.0600 (0.0458)
Wage gap		0.7205*** (0.0476)	0.6653 (0.6653) ***
Trade openness by Macro-sector	Trade openness NR	-0.0002*** (00003)	-0.0002 (0.0002) ***
	Trade openness LI	0.0607** (0.0295)	0.0191 (0.4174)
	Trade openness R&D	0.02043 (0.0098)**	0.0675 (0.0239) ***
Sargan test[a] , χ^2 (prob> χ^2)		672.11 (0.12)	611.68 (0.114)
Hansen test prob > χ^2		1.00	1.00
No. of observations		1893	972
AR (1)		0.00	0.003

Note: Robust standard errors in parenthesis. All independent variables are taken at the lagged value. Full set of time and two-digit industry dummies. * Significant at 10%, ** Significant at 5%, *** Significant at 1%. [a] Sargan test of over-identifying restrictions (Null: Instruments are valid). Time dummies are included in all equations.

Appendix B.6.
Mean and median wage per worker by macro-sector in Brazil and Argentina



Chapter 4

4. Policy implication of structural change: the link between technology foresight and industrial strategies in developing countries. From theory to practice[42]

Abstract

When Technology Foresight (TF hereafter) began to be adopted in industrial countries, it tended to be still somewhat a marginal activity in developing countries. Today globalization radically transformed the range of economic activities that developing countries can perform. Production is fragmented and organized along global value chains. Dense flows of knowledge and technology are available, but need to be fully employed in the framework of coherent industrial strategies.

This paper examines how and to what extent TF programs are needed in developing countries given the new prevailing global context. It argues that the TF and industrial strategies are and must be mutually consistent and they need to be taken seriously, coherently designed and implemented in light of their role to shape economic growth. We provide preliminary support to this argument by discussing the theoretical foundations and justification of TF and industrial strategy, and then reviewing some relevant examples from South Korea, Brazil, Chile and Argentina.

[42] Different sections of *Chapter* 4 have been published – part of the introduction, the literature review, and the case studies on South Korea, Brazil, and Chile – as:

- Pietrobelli, C., and Puppato. F. (2015) Technology Foresight and industrial strategy, *Technology Forecasting and Social Change*, special issue, forthcoming.

4.1. Introduction

The previous chapters of this thesis revealed how and to what extent structural and technological change are crucial in order to promote the much-needed diversification of the Argentine and Brazilian industrial production structure. On the one hand, R&D and knowledge intensive industries act as a transmission mechanism between structural change and higher average wages. Furthermore, while such transmission mechanism is strong and positive in Brazil, it is not significant in Argentina (*Chapter 3*). On the other hand, we demonstrated how structural change is R&D driven in Brazil and natural resources driven in Argentina (*Chapter 2*).

A clear enforcement of R&D intensive industries' productivity and value added is advisable both in Argentina - to a greater extent, given its relatively weaker position - and in Brazil. Such shift would help overcoming the vulnerability suffered by both countries linked to the prices' volatility of the commodities, which should not constitute the only value added of the economy especially when adopting a long-term perspective. Furthermore, the mere exploitation of natural resources tends to be featured by low domestic knowledge generation and value added content. This in turn might inhibit local R&D and engineering activities resulting from the fast expansion of Global Value Chains (GVCs) (Sturgeon and Gereffi, 2013) pushing developing economies in a "low development trap" (Cimoli and Katz, 2003). A foresight approach applied on a global scale is increasingly becoming the dominant development trajectory, especially for developing countries wanting to escape and move forward from such "low development trap" (Sturgeon and Gereffi, 2013). To this end, TF by systematically looking into the longer-term future of science technology and innovation (S&T), can concretely help making better-informed policy decisions (Irvine and Martin, 1984). Since its early inception, pioneered in Japan, TF has tried to help societies and economies to define strategic areas where the future of science and technology would lead.

As a complement of the previous two chapters, this study, by embracing a policy perspective, asks how TF exercises can help developing countries to pursue structural change. During the last few decades the practice of TF spread over a wide range of developed countries as well as regions, companies and other organizations. A growing number of developing countries (*i.e.* Chile, Brazil, Argentina, Ecuador, Uruguay and China), have undertaken TF exercises too. But to what extent does TF really reflect their different condition of developing countries trying to catch up with more advanced ones?

Given their scarcity of resources and lower levels of technological development, developing countries are facing remarkable constraints to catch up with developed countries. Industrial and TF strategies are of remarkable importance to this aim since they both pursue the same goal which has to be consistent with and help strengthen the National Innovation System (NIS). Thus, TF needs to go beyond a pure speculation of where the future will lead and instead foster large-scale efforts to align stakeholders' interests towards the common agreed vision of the future.

This chapter addresses this central question and analyses to what extent TF exercises are essential parts of wider industrial strategies in developing countries by first reviewing and discussing the theory and then analysing four examples from four countries. We essentially compare the TF experience in South Korea with that in three Latin American countries, namely: Brazil, Chile and Argentina.

South Korea, serves as a reference for best-practice, where clever industrial policies combined with a foresighted national vision clearly contributed to achieve a well-defined and unprecedentedly fast economic growth. In Brazil the fusion and mutual reshaping between industrial strategies and TF exercises is demonstrating the country's ability to fully understand the new dynamics of Global Value Chains (GVC). In Chile the government set up an institutional framework embodied by the National Council for Innovation and Competitiveness (CNIC) that would appear to favour the coherence and close connection between industrial strategy and TF with a long-term perspective. In Argentina, contrary to South Korea, serves as counterfactual case study exemplifying how an unstable/volatile macro-economic environment can inhibit the generation of a fertile environment where TF can flourish. Despite this, the government has recently demonstrated a foresight approach thorough the implementation of sectoral funds targeting the private sector.

4.2. What is technology foresight?

An essential fact characterizing today's economic development is the speed of technological change which brought about unprecedented levels of productivity growth (Baumol, 1986). Consequently industrial and trade structures are continuously reshaped towards more complex sets of activities, often following a logic of vertical and horizontal fragmentation within global value chains, with room for outsourcing by multinational companies (MNCs) and foreign buyers driving the process and ensuring its internal coherence (Baldwin, 2011, Cattaneo *et al.*, 2013, Gereffi, 1999). This opens up a new window of opportunities in terms of strategic investments that developing countries may follow to move closer to the technological frontier.

TF represents the concrete effort to overcome this emerging complexity since it systematically embodies a set of programs to study innovation plans and priorities to foresee, shape and direct potential future orientation of technological change (Martin, 1995). Its essential feature stems from the active involvement of a variety of actors such as government, experts, industry and civil society gathering together to define a joint vision of the future (Miles, 2010). Among TF participants the role of experts from science/academia and the private sector is of crucial importance since they might have better insights on technological issues with respect to policy makers and hence they can help reducing the uncertainty brought about the contemporary unprecedented speed of technological change (Hilbert *et al.*, 2009:882). The rationale behind these “exercises” is to generate positive sum games whose outcomes are expected to be more effective in terms of technological advancement, as well as more sustainable in terms of socio-economic benefit than those of isolated initiatives taken by each actor.

Relevant literature refers to TF as to an exercise encompassing a wide range of activities, including: anticipation, forecasting, systematic looking ahead, forward looking activities, strategic intelligence, futures research, technology roadmapping and prognostic among others (Miles, 2010 and Phaal *et al.*, 2004). The pioneering country in TF was Japan that in the 1970s used to call its national technology planning “forecast activity” despite the fact that what it was actually performing was “technology foresight” and perhaps in one of the most refined manners (Miles, 2010). It was later in middle 1980s thanks to Irvine and Martin’s (1984) seminal work inspired by the long Japanese tradition in S&T and TF, that we now call these “forecasting” activities “technology foresight”. The difference is not trivial. On the one hand, forecasting activities, which are typically performed by closed-circles of experts, provide a mere prediction of future contingencies founded on deterministic precision. Their outcome reflects a specific vision of the world, with a single point of view. On the other hand, TF embraces a broader perception of the world that is interactively integrated with policy strategy. TF helps generating insights for forward looking S&T policies that “create” rather than “predict” the future (Miles, 2010) by means of promoting the learning processes (van Dijk, 1991) as well as the dialogue among different disciplines and actors (Elzinga, 1983).

Irvine and Martin’s (1984) work did not only provide the definition and understanding of TF as we conceive it today, but also spurred the proliferation of TF exercises around the world. Right after Japan, France started to perform foresight exercises during the 1980s, followed by Sweden, Australia and Canada (UNIDO, 2005). However, it was during the 1990s that TF gained momentum, spreading also within the UK, the US, the Netherlands and Germany: if one country engaged in foresight activity, others decided to undertake the same exercises too in order to remain competitive (UNIDO, 2005). TF in fact was appreciated as a valuable tool to identify fast, market-oriented and forward-looking innovation policies agreed both by the government and the private sector. Recently, foresight has also spread to developing countries as a strategic tool to reduce their competitive gap with the technological frontier (see section 4). The narrow indication that cutting edge technology productions are only a concern to industrialized countries has gradually been overcome, and the literature in this regard has often referred to this concept as "leap-frogging" (Perez, 1983).

From our perspective, the most distinctive features of TF are the following:

1) In its attempt to predict the future, TF has the potential to influence technology direction and hence to "make the future happen" (Miles, 2010). In fact, by fostering a participatory approach and boasting a strong legitimacy, TF helps building consensus while increasing awareness, accountability, transparency, and therefore ownership and responsibility of future technological developments (Elzinga, 1983);
2) At the same time, a participatory approach ensures the inclusion of new actors who can expand the range of possible strategies beyond the narrow interests of single individuals. For instance TF can significantly facilitate the strategic decision faced by stakeholders to "make or buy" new technologies considering the local knowledge endowments and organization (Lall, 2004).
3) Structural change and the transformation process of the economy they bring about should be endorsed by TF which can help identifying the drivers, implications, and improvements for the introduction of a new technology. TF can be pursued at various levels: organizational, local, regional, national or supranational.[43] All these levels of foresight aim at managing both demographic and socio-economic heterogeneity faced by actors involved in the exercises.

[43] For a comprehensive review of the various methodologies that can combine both quantitative and qualitative methods of TF, see Ciarli *et al.*, 2013.

4) For its effort to try to connect and reorient science and innovation on a national and regional scale, TF is inherently linked with the NIS. TF seeks to foster economic impact by “wiring up” the network between industries, university, governmental bodies as well as the society at large (*e.g.* aging societies, education and training) (Martin and Johnston, 1999 and Andersen and Andersen, 2014).

A number of “failures” intrinsic to innovation activities and S&T policies are usually tackled by TF exercises, such as:

- coordination failures among NIS’ stakeholders that often have different views on the importance of S&T. The balancing of such interests is crucial to wipe out rent-seeking behaviours and bounded rationality (Schlosstein and Park, 2006);
- communication failures, especially when different actors from distinct disciplines (*i.e*. specialized in different subject-languages and forms of communication) express diverging interests and are convened together in order to define a common strategy;
- market failures, since usually S&T programs require a long-term investment that should be weighed against the possibility of temporary short-term losses; and
- political failures since governments too should adopt a long-term perspective on innovation which might not coincide with the political perspective of maximizing consensus in the short-term political interest for the upcoming election (this is often called “dynamic inconsistency”(Ascher, 2009)).

4.3. How is technology foresight related to industrial strategy and structural change?

TF can be envisaged as the connecting thread between two S&T policies’ phases:

- the upstream phase, *via* industrial strategies or plans that have progressively acquired greater prominence along with the increasing complexity in which they are embedded. Globalization, stronger competition and faster technical change have dramatically transformed the range of economic activities that developing countries can perform. Production is internationally fragmented and organized along GVCs. Dense flows of knowledge and technology are available, but need to be fully exploited and employed within coherent industrial strategies. The interdependencies emerging from a globalized competitive setting makes it imperative to devise and follow an appropriate “strategy” to orchestrate responses from the Government, the private sector, and research organizations (Lall, 2004). TF is increasingly becoming a common practice in order to achieve this idiosyncratic synergy throughout the policy development process; and

- the downstream phase, through structural change – or else industrial strategies’ outcome (refer to *Chapter 2* of this thesis for an in depth review of this concept). TF, in fact, should pursue structural change as the uttermost priority by understanding its driving forces and building *consensus* on how the future - and hence the “structural change” - should be shaped. Usually these transformations go along with societal changes, whereby governments play a crucial role in understanding existing dynamics and fine-tuning development goals (Rotmans *et al.*, 2001). Typical dynamics of structural change that should be tackled by TF include: increasing depletion of natural resources, increasing strength of emerging markets, fragmentation of the production structure, the virtualization of many production processes (grid computing, broadband infrastructures, integration of network and databases) (*ibid*).

The increased political and academic scrutiny captured by TF lies precisely in its capacity to support the transition from industrial strategies –the upstream phase of TF policies- into concrete efforts towards structural change –the downstream stage of TF policies-. Yet TF exercises often do not go hand in hand with the concrete identification and design of a policy strategy to promote catch up. The central argument we develop in this paper is that TF needs to be mutually consistent with industrial strategies since both pursue essentially the same objective of industrial development *via* technological catching up. In the following section we briefly outline how the concept of industrial strategy has evolved over time, and how it needs to take into account the more recent changes to the international organization of industry, the emergence of GVCs and the role of innovation.

4.3.1. Different conceptions on industrial policies

Industrial policies have been the object of vivid debates expressing radically diverging views both in the literature and political arena.

Traditionally, the liberal approach argues that the best policy for all countries and in all situations is to liberalize, as free markets dynamics will let countries identify their comparative advantage. The underlying assumption is that products' markets provide the correct signals for investments to which actors respond accordingly. Governments' only duty would be to provide a stable macro-economic environment with clear rules of the game along with the provision of essential public goods. Any further intervention is not required and would distort the already optimal allocation of resources. One of the main weaknesses of the liberal approach is that it overlooks the existence of widespread market failures (Stiglitz, 1989), which tend to be especially pronounced in the field of knowledge and innovation, and that in turn have a central influence on the long-term growth of productivity and income (Hall and Jones, 1999, and Griliches, 1979).

In stark contrast, the literature on technological capabilities maintains that technological change is crucial to emerging countries' economic development, but it is hindered by market failures (Bell and Pavitt, 1993; Katz, 1984; Lall, 1992, 1996, 2001 and, Westphal, 2002). According to this approach, countries' industrial success largely depends upon their capacity to adopt and master existing technologies, even by not being at the technological frontier (Nelson and Winter, 1982). Due to market failures, technology is not freely available and cannot be absorbed without costs or risks. Conscious and purposive efforts to invest in technology specific learning processes and building technological capabilities are critical factors for firms' success (Lall, 1992; Pietrobelli and Battisti, 2000 and Lall, 2004:12).

The technological capability approach provides governments a platform that indeed justifies policy action in a functional and selective manner. Selectivity is crucial, since the cost of offering uniform support to all industrial sectors would be too high and probably ineffective since the learning processes differ by technology (Lall, 2004). Some simple activities require minimal protection and support if the learning period is relatively brief and the information is easily accessible. In contrast, within more complex activities characterized by high entry costs and externalities, newcomers might never enter unless specific policies are implemented to incentivize them to do so.

However, the existence of market failures does not alone establish a case for intervention since it is costly and risky. Stakeholders participation to TF policies calls for a careful assessment of costs and benefits and long-term impacts, wherein government and firms are involved in a constant and mutual learning and experimentation embedded in an institutionalized setting (Rodrik 2007; Rodrik *et al.*, 2004; Morris 2010; Kaplinsky and Morris, 2008; and Sabel and Zeitlin, 2011). This learning process is key both for industrial strategy and TF exercises and the successful experiences of some East Asian economies provide evidence supporting this argument.

4.3.2. Lessons from the East-Asian "tigers"

The experience of the East-Asian "Tigers" (*i.e.* Hong Kong, Singapore, Taiwan and South Korea) serve as a best practice reference of how an active industrial strategy mutually consistent with a TF framework helped promoting fast industrialization and technological development. Even though, the Asian Tigers are far from having followed the same development model, some major common features of their industrial strategy can be identified (Lall, 1996).

Firstly, selective and horizontal policies have been used interchangeably and simultaneously in each country (with the exception of Hong Kong). For example all countries have been investing to create advanced human technical skills, whilst also selectively supporting some sectors with innovation and export subsidies and protection of the domestic market. Secondly, the capability development they pursued occurred within a long time frame. Thirdly, foreign direct investment (FDI) has been used differently by each country. The countries wanting to promote local capabilities development restricted foreign entry and directed their activities to exploit spill-over effects and favouring indigenous companies over foreign ones (South Korea and Taiwan). In contrast, those countries relying on MNCs to promote technology development, persuaded foreign investors to engage in more complex and technology-intensive functions (Hong Kong and Singapore).

The success of these policies may be explained by some significant principles guiding their implementation. East Asian tigers have been constantly selecting and targeting those activities offering better opportunities for learning, technological benefits and linkages. The importance attributed to fostering learning (Lall, 1987, and Lall and Pietrobelli, 2002) implied massive investment in skills generation through education and infrastructures. Learning also extended to strategy formulation and implementation in order to discover the lessons from past mistakes and improve upon them (Amsden, 1989). The private sector was systematically endorsed and supported within this learning process thanks to the active role of public institutions that actively engaged in unusually risky areas (Lall and Teubal, 1998). Finally, exports have been constantly used as a discipline to force early entry in the world markets.

4.4. The role of industrial policies is changing with the emergence of GVCs

Since the early 1990s the twin forces of technology and globalization have led to the geographic fragmentation of industries, where value is added in multiple countries, together with vast improvements in the functional integration of production activities. This evolution generated what is currently known as "Global Value Chains". Today it is difficult to imagine a production that is entirely carried out in just one country (Gereffi and Sturgeon, 2013, and Milberg and Winkler, 2013). In 2009 world exports of intermediate goods surpassed that of the combined export values of capital and final goods (WTO and IDE-JETRO, 2011:81).

These developments pose remarkable challenges as well as opportunities for developing countries' firms and governments. A large body of evidence maintains that despite the potential presence of barriers in some markets and value chains, the interplay between global actors and local suppliers can be a conduit of knowledge and learning experiences that foster processes of capability acquisition, and spill-over to other firms not engaged in the same value chain (Pietrobelli and Rabellotti, 2007). This, however, does not suggest that an initial contact between a local supplier and a global buyer is enough. For instance, a minimum of previous accumulation of skills is typically required for a supplier to engage in contract manufacturing with a global buyer (Morrison *et al*., 2008). There are cases in which existing contracts were discontinued because the supplier was not capable to increase its capabilities to the levels initially expected. Therefore various countries have developed different programs targeted at local firms to become suppliers of global firms. Within this new setting the case for industrial policy and for TF exercises got elevated to a great prominence (Gereffi and Sturgeon, 2013; Pietrobelli and Staritz, 2013, and Sturgeon, *et al.*, 2013). The point is not only to find the country's competitive advantage, but also to tailor it to the requirements of these GVCs.

In the challenge to define multifaceted policies and programs coherent with GVC organization and requirements, careful consideration of the systemic nature of GVCs is needed. An explicit account of the local NIS and its interaction with GVCs is necessary (Morrison *et al*., 2008; Pietrobelli and Rabellotti, 2011, and 2012). Indeed, the relationship between NIS and GVCs is two-way, as GVCs, and in particular lead firms, may support firm learning and innovation as well as improve the NIS (Morrison *et al*., 2008) but may also block them. Similarly, the NIS influences the capabilities, performance and functions of local firms within GVCs. The effective combination of technological efforts and absorption capabilities of local firms and governments may in turn raise the interest of lead firms to support upgrading processes, locate higher value activities and source better quality products locally (Pietrobelli and Rabellotti, 2011).

What is the economic rationale for value chain-related policies? The debate on public policies in the context of GVCs is part of the broader case on the role of states and markets in the development process, and the existence of market and coordination failures discussed above. These challenges are especially problematic in the area of technology, innovation and learning where the contribution of internationalization through integration into GVCs may be most fruitful. The following policy justifications are remarkably important in the context of GVCs. First of all, externalities on other firms are likely to emerge, once one firm signals the potential and the means required to integrate in a GVC. Secondly, in presence of coordination failures, suppliers would not invest to upgrade their production, and lead firms would not support them either. In the absence of long-term contracts, coordination and trust lead-firms and suppliers may engage in learning and upgrading activities to a lesser extent than would be socially desirable. Thirdly, the distribution of rents along GVCs is affected by substantial market failures as well as entry barriers in specific segments (*e.g*. branding and product conception) (Pietrobelli and Staritz, 2013).

In sum, the existence of GVCs is raising and reshaping the need for cleverly-designed industrial policies which should be inherently coupled with TF exercises in their common effort to promote innovation and structural change.

4.4.1. Why does a clear and planned coherence between technology foresight and industrial strategy matter more for developing countries?

In developing countries the need to combine TF exercises with industrial strategies is especially strong.

Firstly, developing countries are often characterized by widespread market failures, poor institutional development (Rodrik, 2000) and a scarce coordination of society and science with public policies, resulting in a missing sense of common purpose (Tavares and Wacziarg, 2001). As a consequence, it is unlikely to expect that in such context each actor would naturally and easily align with the vision outlined by the TF. Information does not flow smoothly and is marked by substantial asymmetries, the rules of the games are not often solid and enforceable as it would be needed, and inter-firm and inter-organization coordination is weak and occasional.

In contrast, more developed countries are generally characterized by better-aligned NIS and actors that are more likely to quickly respond to the incentives launched by the market or by governmental policies. The simple ‘signalling’ effect of a TF exercise is often sufficient to determine behaviours consistent with its long-term objective.

Secondly, TF exercises in developing countries need to be of a different nature. This is because they are seldom frontier innovators but rather users of technologies developed abroad that need to be adopted and adapted to local contexts and conditions. Provided that their final aim is to promote a catching up process, TF should search for existing technologies that could be more appropriate to the needs and level of NIS development, and should be inherently related to their industrial strategy to promote the improvement of technologies.

Thirdly, a major issue identified in the literature concerning developing countries’ technological development is the forecast of the timing of “technology realization”. Developing economies are generally lagging behind in technology development, and the adoption of a new technology, either through domestic firms’ efforts or *via* technology transfer, might be retarded by several constraints which delaying the time of the technology realization. These constraints can include the lack of appropriate regulation and policy standards, human and financial resources, and research infrastructure (Chan and Daim, 2012).

Fourthly, when TF are mutually consistent with the industrial strategy, this can help limit the dynamic inconsistency which is typically stronger in developing countries, where the urgency to achieve positive results in the short-run prompts the tendency to overlook the benefits of long-term investments (Ascher, 2009). This short-sightedness can be mitigated and possibly solved through a shared private and public vision for the future and by turning common commitment into actions (Martin and Johnston, 1999). While investing in key strategic sectors, TF and industrial strategy should create, nurture and strengthen the institutional and physical infrastructure that leads to innovation. This latter type of investments can guarantee a country enough flexibility to reorient its policies in the case of failures and mistakes.

4.4.2. How to achieve a strong link and coherence between technology foresight and industrial strategy?

A careful review of the literature points to some common characteristics between TF exercises and industrial strategies that deserve to be highlighted. First of all private sector involvement is key, and as such it should occur through a participatory approach. Its scope is twofold. On the one hand, it raises the relevance of these exercises by defining the content that public policies should have which is often unknown *a priori* from governments (Hausmann *et al*., 2008, and Hausmann and Rodrik, 2006). On the other hand, it guarantees ownership, responsibility and accountability throughout the process.

Secondly, it is widely acknowledged that well-organized, competent and effective institutions are the backbone of successful innovation and industrial policies (Crespi *et al*., 2014). Participation of entities like the Ministries of Industry, Planning, Education, S&T should encourage actors to adopt behaviours that are consistent with the long-term benefits of TF programs. "Innovation councils" for instance should support long-term strategies whose duration exceeds that of the government, and help mitigate Governments' tendency to overlook the benefits of long-term investments in favour of short-term gains (box 1).

Box 4. 1

Institutional set up of organizations fostering TF

One of the major challenges of TF exercises and industrial policies is to overcome the dynamic inconsistency between short-term gains and long-term benefits typically faced by governmental institutions. This is sometimes achieved through the establishment of a more permanent S&T policy body, able to overcome the political and economic cycles with a foresighted vision. The international experience of such S&T councils varies from country to country. Councils should be seen as a source of strategic intelligence for the innovation policy agenda. According to the extent of their influence on government policy planning, three types of councils can be identified:

A *joint planning* model: which draws from the Japanese experience, where councils serve the government as horizontal ministries of innovation by bringing together different actors from different disciplines to pursue joint projects;

A *coordination model*: based on the Finnish experience, in which the council's main goal is to advice the government by communicating across ministries to direct and align innovation policy. Such advice though is not always necessarily binding, like for the Chilean CNIC.

An *advice model*: as the Canadian case, where the government proactively seeks the council's advice though it does not intend to be restricted from it.

Source: adapted from OECD (2009).

A third important condition for TF and industrial policy's success is a thorough understanding of GVCs logic along with their underlying power relationships. Nowadays GVCs represent one of the main sources of information and technology - as well as market access - for developing countries. With GVCs countries can target specialization niches, but in order to do so they need to develop the necessary skills and technologies to deal with powerful large chain leaders.

In the next section we examine four cases - South Korea, Brazil, Chile and Argentina - where the coherent coupling of TF and industrial strategy has been - to different degrees – evident.

4.5. Case studies: the link between foresight exercises and industrial policies in developing countries

4.5.1. South Korea: technology foresight and its overlap with development policies

The most striking aspect of South Korea's industrial development is the radical shift of its economy from low- to high-tech value added sectors in only a few decades. This was made possible because, over time, TF and industrial policies have become deeply intertwined *via* complex and at time overlapping measures (Chung, 2007). Their main aim has been to respond to the technological challenges raised by global competition.

South Korea's initial development followed an inward-looking model of technology imports until the 1970s, when the economy specialized in traditional low value-added, labor-intensive light industries (*e.g*. textiles). This specialization soon suffered competition from low-cost productions from other developing countries, and prompted South Korea's commitment to search for an alternative development trajectory (Shin and Kim, 1994). The country's new specialization focused on high-value/capital intensive heavy and chemical industries and high-tech home-grown technologies such as electronics (*e.g.* semiconductors, mobile phones, displays and mobile internet) (Kim and Dahlman, 1992). The presence of large *chaebols*[44] like Samsung, Lucky-Goldstar (LG) and Hyundai represented a key factor in contributing to this radical shift in the structural change of the economy.

The industrial policies endeavoured by the Korean Government were inherently interventionist, pervasive and sought to promote indigenous technology while improving local technological capabilities (Lall, 2004). Vertical policies targeting high-tech niches coexisted with horizontal ones

[44] *Chaebols* were South Korean private businesses owned by single powerful families and they comprised several smaller members and units, which all maintained a close connection with the government (Chung, 2007).

aimed at developing endogenous capabilities, improving local infrastructure and implementing R&D investments across a variety of sectors (Chung, 2007). This unprecedented economic growth would not have been possible without government interventions *via* the six National Development Plans, designed and implemented between 1962 and 1991. From a careful analysis of these plans some key features of the governmental intervention emerge.

The first is the single-minded objective to pursue economic growth, which has been the foremost goal for all South Korean governments. Such goal prevailed even at the expense of others, like equity or poverty reduction. This attitude turned out to be essential in directing and forging Korean mentality and rejuvenate institutions and leaders (Chung, 2007).

The second feature was that trade policies were complementary to the industrial ones and geared towards structural transformation of the economy's specialization. They were oriented to promote capital goods imports (rather than consumer-ones), and FDI was kept out of the picture for many years unless it was deemed necessary for accessing new technologies (Lall, 2004). These policies were constantly accompanied by stringent performance requirements and were gradually phased out as companies demonstrated the ability to compete.

The third was the government's ability to engage the private sector in the development process within both TF exercises and development plans by stimulating its ownership and responsibility. Private sector trust in government action was based on the deep-rooted legitimation of the state and on "collectivism".

Korean foresight exercises date back to the 1990s, after the national development plans had taken off in the 1960s. Foresight activities tended to have a strong technological connotation and so did the earlier national development plans. Despite the different terminology in fact they did the same job. National development plans foresaw the future by identifying the strategic sectors in which to invest, and they did so by combining both long and short-term perspectives.

Since the 1990s, TF exercises in South Korea have typically resulted in 5 year-plans targeted to problem solving and to understanding which general-purpose technology was worth investing in. TF results are incorporated in the wider S&T Plans which are usually longer-term (5 to 30 years). The rationale is to better connect targeted on-spot technologies selected during TF exercises with the overall NIS long-term plan and projections (see Yim, 2011, and Shin and Kim, 1994 for a comprehensive review).

The conceptual and practical link between South Korean TF exercises and industrial development makes it a suitable example to follow for other emerging economies (Kim and Dahlman, 1992). During the implementation of TF investment technology has been visibly supported by the Korean government and became integral part of the 2013-17 S&T Plan where particular emphasis was paid to renewable energies (Yim, 2011). However, the adoption of TF as a strategic tool for policy making did not come without difficulties, and the government repeatedly went through a trial-error process.

The first national R&D plan, which started in 1982, stressed the need to generate indigenous capabilities in semiconductors, steel, automobiles and shipbuilding (Hwang, *et al*., 2011). During 1982-1992 a total of 2400 projects received massive government investments (US$ 207 million of which more than two/thirds were directed to R&D). Many research departments in firms were founded (Shin and Kim, 1994) and the private sector R&D investment also increased from about US$ 297 million in 1982 to about US$ 3044 million in 1990. However, in spite of these efforts, R&D projects' commercial performance was rather unsatisfactory. Only about 4% of the 469 R&D projects funded by the government, and only about 30% of the 589 projects jointly financed by the government and the private industry, were successfully commercialized (Shin and Kim, 1994). The lack of expertise in R&D management of the government's officials was deemed responsible for such a poor performance, motivating the establishment of R&D budgets under the supervision of entrusted specialized organizations for each line ministry (Lee *et al*., 1996).

The last TF exercise in South Korea was conducted in 2012 and it focused on the "social needs" of the Korean society. The novelty of the exercise lied not only on the new typology of selected sectors (including protecting health with personalized medicine and treatment, model for forecasting health conditions, electric home appliances for future energy saving, among others) but also on the methodology adopted to detect changes in the R&D environment (Kim *et al*., 2013:72). The New and Emerging Signals of Trends (NEST) developed by the Korea Institute of Science and Technology Information (KISTI) firstly developed 8 years ago, is one of them. By combining quantitative and qualitative methods, NEST seeks to formalize the identification of weak signals[45] and emerging technology trends based on

[45] Weak signals are events, accidents or rare occurrences that are thought to trigger future changes (Kim *et al*., 2013:52).

massive analysis, inference techniques, and Delphi studies from worldwide expert networks in order to assist researchers to better perform their research activities. NEST acts as a sort of "unsupervised bottom-up approach" since crucial decisions taken during the process are made by information technology and data mining algorithms. Human expertise is foreseen only during the assessment and at the end of the process (Kim *et al.*, 2013:72).

4.5.2. Technology Foresight in Brazil: a value-chain approach to industrial strategy

One of Brazil's historical challenges – and the key topic examined in this thesis - is structural change which represents the capacity to diversify the production structure beyond the mere exploitation of natural resources and to raise the technological content of exports *via* new and higher-productivity industries. Within this context, Brazil has been recently reconsidering its approach to industrial strategy to exploit the potential offered by GVCs.

In this country, the proliferation of TF exercises began systematically at a national level in the late 1990s with "Brazil 2020". However, national commitment to S&T policy started much earlier through S&T plans (the first Science and Technology Development Plan took place already in 1973-74) and business-level TF (Popper and Medina 2008, and Chan *et al*., 2012). During this initial phase, TF exercises were guided by large banks and companies such as BNDES and PETROBRAS. TF took the form of prospective and extrapolative studies (Porto *et al*., 2010). Nevertheless, largely because of the tumultuous period of political and economic oil gas crisis, as well as the Brazilian transition out of the military government, these techniques led to miss-specified predictions motivating the inclusion of additional foresight techniques imported from Western countries (such as scenarios) (Porto *et al*., 2010).

The newly adopted techniques allowed TF exercises to strengthen stakeholders' coordination. They took place every 2 or 3 years and their main goals included:

- the identification of the strategic sectors where to invest as for example with the 2002 Brazilian TF Program, that targeted civil construction, textile and garments plastics, wood and furniture; and
- the strengthening of investment in key infrastructures in order to be able to accommodate and take advantage of technological change, as with "Project Brazil 3 Times" (Mojica, 2010).

Nowadays, the principal institution responsible of TF is the Centre for Strategic Studies and Management (*Centro de Gestão e Estudos Estratégicos* – CGEE). In 2005 CGEE together with FINEP (*Financiadora de Estudos e Projetos,* Research and Projects Financing Corporation) defined the "Brazil 3 Times" project, a strategic study that examined scenarios to characterize the country's future in 2007, 2015, and 2022 respectively. The use of scenarios contributed to raise awareness of the vast amount of local assets and of the huge Brazilian market (Gouvea and Kassicieh, 2005). By acknowledging Brazil's goal to catch up with foreign competition in international markets, this project highlighted the relevance of GVCs for the country's technology policy (CGEE website).

4.5.2.1. Foresight and GVC-oriented Industrial Policies in Consumer Electronics in Brazil[46]

An instructive case of how GVCs intersect with national industrial policies and TF can be found in Brazil's recent efforts to leverage its large and growing internal market to build domestic capabilities in the consumer electronics sector.

Brazil's overall trade performance in the consumer electronics sector recently turned negative, with a decline in exports and a very rapid increase in imports to fulfill the rising demand of the local middle class. These rapid market shifts brought a new set of players to the fore, namely Apple, the many makers of Android-based smart phone handsets, and the contract manufacturers that produce the bulk of these products such as Flextronics (from the USA and Singapore) and Foxconn (from Taiwan). Market growth and access to Mercosur is providing Brazil with the leverage to demand local production and content from consumer electronics and communications GVC lead firms, who in turn have put pressure on their key global suppliers to make investments in Brazil. To do this Brazil is bringing to bear a range of old and new policies aimed at spurring local production in the electronic sector. The key laws and programs to stimulate local production are listed and described in Table 4.1.

At first glance Brazil's current industrial policies may appear similar to the old-style import-substitution ones, but they are remarkably different in several aspects. As GVCs bring new actors and industry structures to the fore, the challenges, opportunities, and outcomes related to these policies change. A remarkable dissimilarity with past protectionist policies is the reliance on

[46] See Gereffi and Sturgeon, 2013, for additional details.

global sourcing which implies openness to knowledge and technology from abroad. Moreover old-style protection policies stifled competition, while the global battle to provide global suppliers represents a constant inducement to improve efficiency through the specialization in fine segments of the value chain, reflecting comparative advantage as much as possible.

A centrepiece of Brazil's strategy to increase local production of consumer electronics has been to attract global contract manufacturers, known in the industry as electronic manufacturing services (EMS) providers. As electronic lead firms such as Apple and Hewlett Packard continue to outsource manufacturing, contract manufacturers have become increasingly important players in the component purchasing, assembly, test, and after-sale service functions of electronics GVCs. Seven of the 12 largest contract manufacturers are based in Taiwan, and they all suffer from low profit margins (just 2.4% in 2011) due to intense competition. They fill an increasingly complex role in the electronics GVCs since they must not only work closely with lead firms to develop products and meet tight production schedules, but also with a worldwide network of component manufacturers and distributors to ensure that they meet demand and keep their lines operating at, or near, full capacity. They perform an important role of coordination of local suppliers, reducing uncertainty of final consumption by presenting market opportunities and setting, showing the standards to fulfil markets requirements, and making investments with as large minimum scale requirements as possible.

Thanks to Brazil's industrial policies and direct pressure on the company from policy-makers, Foxconn has begun to assemble iPhones, iPads and most recently iPad minis for Apple in Brazil. While Foxconn currently imports 90-95% of its components, the company is likely to begin to manufacture components, including displays, in Brazil. Recent negotiations with the Foxconn factory in Brazil suggest that once production is at 100% (projected to be 2016), Foxconn will be manufacturing additional components including cables, cameras, touch-sensor glass, LED products, and printed-circuit boards (Taipei Times, 2012).

The story of Hewlett Packard (HP) also offers interesting insights on the integration between foresight and industrial policies in the GVCs. HP uses three global contract manufacturers to produce in Brazil (Foxconn, Flextronics and Jabil Circuit). But hardware production is only part of the picture. In meeting the requirements for local R&D spending (4% of sales), HP Brazil employs 400 engineers and researchers in its lab in Southern Brazil and has contracts with another 1,000 collaborators from universities and research centers in the country. It also founded four software centers working on local customer-specific applications, while contract manufacturers are being used to help meet the R&D spending requirement. Two of HP's research centers have been set up in collaboration with the Flextronics Institute of Technology's (FIT): the Radio Frequency Identification (RFID) Center of Excellence, which has worked on over 100 RFID-related projects with HP; and the newer Sinctronics IT Innovation Center, which focuses on environmental compliance and product recycling. R&D capacity, just as like the manufacturing capacity of contract manufacturers, can serve multiple lead firms. FIT performs R&D on behalf of competitors like Foxconn and Compal which do not have the R&D facilities in Brazil, and has therefore been able to develop economies of scale in R&D with remarkable externalities.

The presence of global contract manufacturers in Brazil generates a number of immediate advantages. It creates new jobs – Foxconn currently employs 6,000 in Brazil and could add 10,000 more jobs by 2016. Moreover, because contract manufacturers serve multiple customers, their manufacturing capabilities can satisfy local content requirements for multiple brands as production is flexible enough and capacity can be switched towards different product categories and firms.

In sum, the focus of Brazil's industrial policy to attract investments from contract manufacturers, as well as GVC lead firms, signals a sophisticated understanding of the dynamics of the electronics GVCs by policy-makers. Contract manufacturers provide a leading edge, flexible, and scalable platform for local production and R&D. Furthermore, the Brazilian case suggests that learning within GVCs is possible if supported by appropriate policies. Arguably, the government understood that TF needs to be fully inserted into a modern industrial policy approach to strengthen the country's innovation capacity.

Table 4. 1.
Brazil's electronics-related industrial policies

Policy mechanism	Details
Informatics Law:	The Informatics Law of 1991 initially sought to foster local production of electronics and R&D through the use of Basic Production Processes (PPBs) and R&D investment quotas.
Local content incentives:	Firms are encouraged to manufacture in Brazil through product-specific PPBs – "the minimum group of operations, within the industrial plan, which characterizes real industrialization of a certain product". PPBs reduce industrial product taxes (IPI) on final products, raw materials, intermediate products and packaging goods associated with the promoted product from 15% to nearly zero. Reduction in ICMS (state VAT) also applies in many states. PPBs are product, not company specific; only those products meeting the PPB's criteria receive benefits. They are defined and monitored by the Ministry of Science, Technology and Innovation (MCTI) and Ministry of Development, Industry and Foreign Trade (MDIC). PPBs set 'nationalization indices' that define how much of the promoted product must be local in content in order to retain the incentives offered. For example, the PPB for computer tablets in 2012 set the nationalization index at 30% and targets to raise it gradually over time.
***R&D spending requirements*:**	Firms must invest 4% of gross revenue from promoted products in local R&D. The key stipulation is that R&D must involve the discovery of a new technology or the development of new workforce capabilities, and not simply extend an existing, mature technology.
Incentives for the semiconductor industry:	The Brazilian Microelectronics Program, launched by the MCTI in 2002, sought to support segments of IC manufacturing by offsetting exorbitant capital requirements involved in building a foundry with the latest technological capabilities. This focus on microelectronics continued through the '*Política industrial, Tecnológica e de Comércio Exterior'* (PITCE) enacted by President Lula in March, 2004. PITCE focused on developing outward-oriented software and integrated circuit industries, among various others. In 2007, the government enacted PADIS, a subset of the broader industrial policy '*Plano Brasil Maior*' to develop local semiconductor and display industries by targeting companies investing in R&D and manufacturing capabilities in Brazil.
Plano Tecnologia da Informação TI Maior:	Software is the fastest growing IT market segment in Brazil (16% annual growth rate during 2011-15, Business Monitor International 2012). Brazil has long had a viable cluster of software SMEs. *Plano TI Maior* is the most recent attempt to scale these firms up, the majority of which remain small and unable to compete outside Brazil. The most important component of *Plano TI Maior* is CTENIC, an equivalent of the PPB for software. This certification is currently under development and will define what constitutes 'Brazilian software'. Explicit efforts to bolster software development in Brazil are important, as software development costs are considerably higher in Brazil than in China and India.

Source: adapted from Gereffi and Sturgeon, 2013.

4.5.3. Technology foresight in Chile: the National Innovation Council for Competitiveness's efforts to foster innovation and address dynamic-inconsistencies

The Chilean innovation system has been suffering from several bottlenecks (OECD, 2013). The most difficult to address has been the poor institutional coordination which inevitably reflected in the low trust that private sector had towards public/private business relations. Nevertheless, the Chilean political will has recently become more supportive of innovation *via* various reforms encouraging firm's R&D investments. TF programs were launched only recently (beginning of 2000) on a national basis and they were adopting Delphi methods to select the key economic activities to promote (Popper and Medina, 2008).

A recent concrete institutional effort towards the strengthening of the NIS, which is key to TF exercises, has been made through the establishment of the National Innovation Council for Competitiveness (CNIC) in 2005, the most important institutional innovation in the last 30 years (Zahler, *et al.*, 2014). CNIC embodies a permanent private-public partnership advising the Chilean government on long-term strategies related to innovation and competitiveness. The Council directly responds to the President of the Republic and in fact it should serve as the interface between the President and various Ministries (Finance, Education, Planning, etc.).

Inspired by the Finnish experience and hence based on a coordination model (see Box 4.1.), CNIC serves as a platform to agree on policy priorities with a clear and consistent consensus. Its guidelines are part of the White Paper (CNIC 2010). Every 4 years CNIC provides an evaluation of the accomplishments achieved, as well as an evaluation of the Chilean Industrial Development Agency (CORFO) and the National Council on Science and Technology (CONICYT). For its inherent nature, CNIC can be regarded as a foresight-oriented organization since it is entrusted directly by the government to define the direction of national innovation strategy.

Along with CNIC, the government also established the Innovation for Competitiveness Fund (FIC) that finances CNIC's decision once they obtain governmental approval. FIC's resources draw from a levy on mining introduced with the mining law (Zahler *et al.*, 2014). The CNIC actively engages with its counterpart in the Government, the Ministerial Commission for Innovation (*Comité de Ministros para la Innovación* – CMI) funded in 2007, an implementation body of innovation policies.

CNIC's operative mandate is based on three pillars, namely:

- fostering a high-quality lifelong learning to increase the quality of human capital;
- supporting scientific communication and dissemination aimed at applying knowledge to concrete productive and social needs; and
- enhancing private sector involvement in the design and implementation of foresight exercises and concomitantly fostering internal R&D (Crawford, *et al*., 2010).
- One of CNIC flagship programs was the "Cluster Program", a vertical policy inaugurated in 2007 (and now discontinued) which witnesses the Council's capacity to introduce more selectivity through foresight within innovation policies (Zahler, *et al*., 2014).

4.5.3.1. CNIC evaluations and critiques

The international experience of national innovation councils hints by and large to a continuous trial and error process before they set to work efficiently. The Chilean case is not an exception in this regard. The council in fact had to deal with a number of structural problems (*i.e*. the change of government in 2009 discontinued some already initiated programs).

A certain degree of experimentation has been crucial in order for CNIC to adapt to the context in which it operates. Some major bottlenecks have been identified, namely: the role of the Council should be set clearer so to guarantee its neutrality as an advisory body; the council should also improve the communication among different government bodies and agencies so as to generate an efficient and transparent social networking; and the legitimacy of the Council should be founded on clear basis in the parliamentary legislation (and not on a presidential decree) (OECD, 2009).[47] This aspect is especially important for TF policies since a clearer legitimacy can foster the council's capacity to solve dynamic inconsistency issues (OECD, 2009).

All these recommendations have to deal with a more sophisticated level of institutional set up required for the CNIC to operate more effectively. They also highlight the fact that technological change needs to be sustained by appropriate institutions able to overcome the political dynamic inconsistency that prevents the NIS to flourish. CNIC's institutional answer to foresight policies requires a considerable commitment in many respects. The council

[47] In the UK the council is defined on a parliamentary basis, and a simple ministerial decision is effective in signalling an intention so to align actors towards it.

should actively engage to align ministries and agencies towards a common vision. Ministries in turn have to give up part of their autonomy in favour of a national innovation policy. Ultimately, the challenge for CNIC is to establish itself as a credible advisor of the government and help systematize competitiveness and innovation policies (OECD, 2009). In addition, a participatory approach should be constantly encouraged. CNIC aims at becoming an arena where critical inputs/information on the Chilean NIS can be discussed, and where a collective and strategic intelligence can be pursued by gathering together different actors with diverging interests.

In sum, despite significant investments and a favourable macro-economic environment, Chile has not yet succeeded in becoming an innovation-based diversified economy (OECD, 2013). However, institutions like the CNIC can help tackle and solve Chile's NIS inherently highly fragmented nature. A certain degree of experimentation is still needed to improve its role and functioning, but efforts to learn from past initiatives have been a central and very appropriate feature of its experience.

Two important outcomes emerge from the analysis of the Chilean case. First, CNIC has the potential to act as a key foresight actor within the Chilean NIS since initiated a process to establish an innovation culture in the country with a stronger interaction between the public and private sectors. Second, and consequently, this institutional set up promises to help the country address the typical dynamic inconsistency and distance between TF and an appropriate industrial strategy.

4.5.4. Argentine socio-economical context for technology foresight

It is widely acknowledged that a volatile macro-economic environment can undermine the effectiveness of TF policies, especially in developing countries, where the regulatory power is often incomplete and uncertain (Ascher, 2009). Argentina represents a paradigmatic case in this sense, as its history demonstrated how an unstable macro-economic policy, along with - and leading to – high uncertainty, can weaken the provision of an ideal environment where TF can flourish.[48] As we shall see in the next section, the

[48] The cardinal role of institutions is even more evident when comparing the country with Canada (see Chudnovsky, *et al.*, 2000). During the 1950s, both countries shared similar initial endowments - agricultural wealth, large-scale European immigration, strong ties with international markets and growing capital institutions - as well as growth rates which nevertheless later diverged, leaving Argentina much behind with respect to its counterpart and suggesting how important the role of culture and institution is in generating sustainable growth holding every other aspect constant (*ibid*).

link between the Argentine industrial policy and TF is not straightforward since industrial policy in first place has been volatile and discontinuous and rather more visible in isolated cases/sectors such as the biofuel one (Katz, 2015). Despite this context, the country seems to have embarked a series of reforms in order to promote TF in a more systematic manner, mainly by launching specific horizontal/sectoral funds, fostering the involvement of private sector in the R&D generation,.

4.5.4.1. Argentine technology foresight experience: multiple actors multiple plans

Similarly to what occurred in Brazil, TF exercises in Argentina began recently, around the 1990s, in spite the fact that innovation polices actually had a quite long tradition in both countries, dating back to the 1950s, within the framework of import substitution strategies. The Argentine NIS evolution should be interpreted as the intentional governmental effort to establish S&T policy institutions, in face of a deeply uncertain macro-economic environment. It is important to note, though, that the foresight mentality in the country appeared to be, until the recent past, much more leaned towards the “science” rather than the “technology” side of the S&T policy (Anlló, 2015). This bias might in turn provide the justification behind the latest S&T National Plans’ strong emphasis to compensate for such limit, by re-orienting resources towards businesses and their linkages with R&D institutions (IADB, 2014).

The following paragraphs will exemplify the main TF policies implemented so far, paying particular attention to the role of foresight institutions and plans. Next, on the basis of the analysed documentation and interviews, we will describe its major strengths and weaknesses.

A remarkable group of research bodies is rounding out Argentine NIS: the National Scientific and Technical Research Council (CONICET), the National Agricultural Technology Institute (INTA), the National Atomic Commission (CNEA), and the National Institution for Industrial Technology (INTI). CONICET with its 20 public research labs can be regarded as the national scientific council, similar to the French National Centre for Scientific Research (CNRS). Commonly targeted disciplines were biomedicine, physics and chemistry. More recently, business sector and civil society also founded research centres and a small but increasing the number of research labs (IADB, 2011).

TF exercises, under the form of perspectives and scenarios, mildly began to take place during the 1990s with the “Technological modernization plan”

(1994), co-financed by the IADB (Popper and Medina, 2008).[49] Subsequently, TF practices loomed large through "The National Plan for Science and Technology" (1998-2000) epitomizing the governmental effort in TF, *via* the establishment of two key S&T institutions: the Secretary of Science and Technology (SECYT), and the National Observatory of Science and Productive Innovation (ONCTIP, set up by SECYT). ONCTIP, an inherently foresight institution, carried out diagnostics and perspectives foresight for the country, including socio-economic and demographic scenarios[50], along with the support of three key strategic sectors: biotechnology, chemical and textile industries (Mari, 2005).[51]

"Sectoral funds" launched in the 1990s, embody a remarkable step forward in TF policies reflecting a radical shift from the neutral, horizontal logic of technological/industrial development, to a vertical, more selective one. In this renewed framework, the so-called "triple helix" (academia, businesses, and the government) was regarded as indispensable to select the most promising sectors that could compete on a global scale. Two central pillars that appear to be common to all the national science and technology and innovation plans – including the last one 2012-2015 - are: the exploitation of the comparative advantages in the field of natural resources and the development of industrial capabilities by means of increasing the level of employment.

The National agency for the promotion of S&T (ANPCYT) was established in 2006, directly responding to the SECYT. Supported by the financial and strategic role of the IADB, ANPCYT key foresight goal was promoting scientific and business innovation activities by strategically steering sectoral funds, including:

- FONCYT for the promotion of S&T policy;

[49] The role of IADB in the Argentine TF is quite remarkable. Among the other things it provided the country with the funds start the sectoral innovation polices.

[50] Such as the Technology Employment and Training exercise.

[51] Unfortunately all these programs were interrupted due to the 2001's political and financial crisis. Later in 2003 they came back into action with the "Strategic Mid-Term Plan of STI" for 2015 involving more than 4000 experts in TF methodologies - such as panel, perspectives and surveys. Targeted areas/sectors were: the strengthening of the NIS, the improvement of S&T activities, and raising S&T public and private expenditure. The plan foresaw the implementation of new interesting TF institutions/instruments such as: the Sadosky foundation whose main aim was to finance R&D public/private partnerships in the field of ICT, and the Fund to improve capacity building (FOMENI) supporting the informatics/ICT sector (Mari, 2005).

- FONTAR financing innovation-oriented projects proposed by private firms in order to enhance their competitiveness;[52]
- FONSOFT focusing on the ICT and software industry; and
- FONARSEC bridging public and private effort towards a common S&T goal within a specific sector.

A further remarkable step forward within TF policy occurred towards the end of 2010s with the foundation of the Ministry of Science and Technology (MINCYT). Its main goals were the systematization of the TF and S&T policy interventions along with the strengthening of vertical (sectoral) policies started in the previous decade (MINCYT, 2009). In practice MINCYT represents a natural evolution of the SECYT, since they both share the same structure and goals (Anlló, 2015). The role of MINCYT in promoting TF policies is key in many respects. For example the National Science and Technology and Innovation Plan 2012-2015, elaborated with the participation of more than 350 experts involving representatives from the private sector, seeks to pursue two key objectives: institutional strengthening, and a better identification of the priorities in terms of human resources and financial instruments (Aggio, *et al*., 2014).

Of particular note in terms of TF measures, is the establishment of two key additional funds falling under the umbrella of FONARSEC: the Technological Innovation Fund (FITS, Fondos de Innovación Tecnológica Sectorial), and Sectoral Innovation Fund (FTS, Fondos Sectoriales en Alta Tecnología) (Aggio *et al*., 2014). Although they responded to the logic of the previously described sectoral funds, they place a greater emphasis on technological development. Their mail goal is to tackle coordination failures derived from the incorporation of technological change within each sector so to generate greater impacts in a shorter time frame targeting businesses competitiveness, especially SMEs (IADB, 2011). But how do these funds work in practice?

Within FTS sectors are initially chosen depending on their potential to generate knowledge diffusion, profitability. Subsequently, such selection becomes object of a negotiation between the MINCYT and international donors (usually the IADB and the WB). During the period (2010-2015) selected areas were: biotechnology, nanotechnology, and ICT with an overall investment of about 72 million US dollars (of which 60 million from the IADB

[52] In 2006, the fund financed 527 projects for a total of 50 US$ million. The non-reimbursable funds were entirely targeted to SMEs. In the period 2003-06 period, 33 US$ million were approved for 1100. When internationally compared, the Argentinean program appears to be poorly funded (Niosi, 2010). If Argentina wanted to spend the equivalent of the Canadensis Industrial Research Assistance Program (IRAP) it should reach 150 US$ million annually - not just 10 million.

and 12 million from the Argentine government) (Aggio *et al*., 2014). An inherent TF approach making extensive use of roadmaps and technological perspectives, was evident in the case of the agricultural industry (Bocchetto *et al*., 2014). Experts' engagement was crucial in order to strategically depict the world benchmark in relevant agricultural sectors and the way in which Argentina could and did find its niche in the global arena. FITS' selected sectors were: forestry, beekeeping, diary products, seeds, fishery and a more efficient usage of water in the production of food (*Ibid*).

FIST methodology is slightly more complex than the FTS one, as its core activity spanned over broader "socio-economic areas" –rather than specific sectors - where to invest, namely: energy, health, climate change and environmental development, agroindustry, social development and energy (Aggio *et al.*, 2014). *Ad hoc* sectoral technological councils were established for each of the selected socio-economic areas and they were in charge of formulating "proposal profiles" to be approved by the MINCYT. Reflecting TF methods and logic, sectors were chosen based on two major features: their relevance in the overall economy, and their capacity to trigger R&D- and S&T-based improvements (IADB, 2011). Again, particular importance was placed on the "business approach": disbursements to the private sector for R&D and innovative activities were conditional to the results actually achieved during their implementation, a factor that concretely supported MINCIYT monitoring and evaluation system (IADB, 2014).

Table 4.2. reports FONARSEC - FITS and FIST - investments originating from the Argentine government and the counterpart (international donor and/the private sector) for the period 2010-2012.

Table 4. 2.

Sectoral funding divided by source for the selected sectors from 2010 to 2012

In million US dollars and in % - last column-

Selected sectors and socio-economic sectors	FONARSEC funding million US dollars	Counterpart million US dollars	Total investment million US dollars	FONARSEC participation%
Nanotechnology	18.0	9.0	27.0	23%
Bio-Vaccines	16.2	7.7	23.8	21%
ICT	12.6	11.8	24.4	16%
Health	11.8	18.5	30.4	15%
Solar energy	8.3	11.1	19.4	11%
Agro-industry	6.3	10.4	16.7	8%
Agro-biotechnology	4.1	1.8	5.8	5%
Total	77.3	70.3	147.6	100%

Source: Kohon and Mochi (2013) and FONARSEC.

Nanotechnology, bio-vaccines and ICT constituted the three most important sectors in terms of resources' allocation. According to the IADB (2014) the FITS and FIT were successful both in terms of resource commitment and execution levels.

The latest S&T plan "Innovative Argentina Plan 2020" manifests the quite ambitious attempt to overcome the country's 50 years delay in the field of ICT, within the next 20 years through a foresight approach. The document in fact, shows how to look and learn from the best practices of ICT in the world *(i.e*. Finland and Malaysia) in order to promote the technology transfer to foster the generation of knowledge-base society (MINCYT, 2020). One example of sectoral TF policy's excellence contemplated in the 2020 National Innovation Plan is the bioenergy sector that sees Argentina as a world leader in biodiesel production with an active governmental engagement in providing a suitable regulatory framework to support its production. Besides, within the 7th European Commission Framework Program on Research and Innovation, the "ALCUE –KBBE" project was launched. Its main objectives was fostering cooperation in the field of bio-economy in Latin America and the Caribbean, whereby Argentina played a major role in the generation of a roadmap "Towards a Latin America and Caribbean Knowledge Based Bio-Economy in partnership with Europe" (German Bioeconomy Council, 2015).

4.5.4.2. Technology foresight challenges and results in face of a difficult macro-economic environment

The key message emerging from this case study is that the link between industrial and TF policy in Argentina has not yet been fully developed since to date both the industrial and technological dimensions appear to have been successful in few isolated cases (*i.e.* biofuels). The lack of macro-economic stability appears to have been the major cause behind the Argentine technological gap with other developed economies, which still remains wide (IADB, 2014).

This is where TF policies have a key role to play and the Argentine government seem to have understood the paramount importance to orchestrate a strategic alignment of TF system in order to support the private sector development. The key message is to promote the competitiveness of enterprises by fostering participation in the S&T system, while reducing the business-innovative-related risks. Concomitantly, investments in human resource endowment and S&T infrastructure have been undertaken (IADB, 2011) witnessed by the large amount of investments both from the government and international donors (*i.e*. IADB and the World Bank (WB)) to promote TF (IADB, 2014).

In our opinion Argentine's TF bottlenecks can become the starting point to fine-tune the country's TF policy in a more effective manner. To a useful approximation, the main shortcomings of its TF policy can be classified, in order of importance, into four main groups, namely:

1. *Low level of investment, both private and public.* For instance the effectiveness of the Mid-term Plan of S&T 2015 was affected by the insufficient level of S&T investment both from the public and the private sector (Popper and Medina, 2008). In fact R&D expenditure as percentage of the GDP was stationary at 0.44% in 2004 and 0.52% in 2008 but they still remain below the average of the Latin American region (0.67%) (IADB, 2014). Likewise, the private sector's contribution to R&D investments is about 29% - against an OECD average of about 68% (*ibid*).
2. *Policy lack of clarity and focus*. National development plans seem to pursue similar types of objectives over time. For instance health, human development, energy, education and housing were foremost goals both in Argentina Plan 2020 and in the "Bicentenario Plan 2006-2010" (SECYT, 2006). Overall TF policies seem to have suffered from a lack of prioritization due to the presence of too many sectors being financed. In the latest TF exercise the government is targeting more than 20 industries ranging from the agricultural sector - which alone comprehends 17 subsectors including cotton, oil industry, chemistry, etc. (Idígoras and Papendieck, 2014) - to the ICT industry - which covers more 5 subsectors - with further subdivisions including the industry, agriculture, services, the digital industry and security (2020 Plan).
3. *Poor institutional coordination*. In spite of the significant progress in the NIS' articulation, epitomized by the establishment of the MINCYT, a higher coordination among TF institutions and the private sector remains a priority. Due to financial market failures and short-termism, the linkages between universities/knowledge centres and industries appear to be scant and discouraging firms' effort in technological investments. Another critical example derives from CNEA and its mismatch between supply of knowledge and firms' demand (IADB, 2011). Despite its remarkable advances in monitoring climate change (like in the Bariloche Atomic Centre) (Katz, 2015), literature suggests that its only client was the public sector (Niosi, 2010) and the

international market (Katz, 2015) rather than the domestic one (Niosi, 2010).[53] Furthermore, although the ANPCYT has developed a remarkable TF monitoring system, its impact assessment capacities appear to be poorly defined (IADB, 2011).

4. *Discontinuity of TF activities* is a direct outcome of the unstable socio-economic environment, a factor certainly discouraging long-term investments in industrial and technological development *via* TF. The financial default in 2001 is one emblematic episode conducive to the abrupt interruption and then recovery of TF policies, *albeit* with a drastic reduction of investment. This was the case with FONTAR, whose programs were interrupted in 2001. After the crisis the program re-merged financing the same amount of pre-crisis investment. The main difference with respect to the past was that, due to the 2001-02's abrupt devaluation, the investment decreased by 66% in US dollar terms (Niosi, 2010). Despite subsequent mild increase in the level of credit as well as number of projects being financed (from 331 in 2003 to 1741 in the period 2004-2006) the R&D financing programs still fail to provide a satisfactory level of investments to promote foresight policies (see point 1) (*ibid*).

These limitations call for a redefinition and clarification of the rules of the game which should be tailored to enterprises' needs and focused on a more limited number of sectors in order to reduce uncertainty and to provide MINCYT with the power to coordinate TF policies in a systematic manner. The last TF developments seem to point towards this direction demonstrating the importance to build up political *consensus* allowing TF inception and continuity. Selectivity has to become a priority since the costs of providing uniform support to many industrial sectors can undermine policies' effectiveness, especially when financial resources tend to be scarce, as in the Argentine case.

4.6. Summary and conclusions

In this paper we have argued that the link between TF and industrial development strategy needs to be taken seriously in light of its role to shape technological change and economic growth. Since TF and industrial strategy essentially pursue the same goal, they need to be coherently designed and

[53] Only the INTA appears to have successfully managed the generation of knowledge and technology transfer in the production sector (Niosi, 2010).

implemented. When TF began to be adopted in industrialized countries, it tended to be still somewhat a marginal activity in developing countries. It was then believed that TF and its prediction of the future was a matter that only highly industrialized countries could endeavour, being more engaged and interested in frontier and “new to the world” innovation.

Today globalization, increased complexity, competition and fast technical change make it imperative also and particularly for developing countries to specialize by technology and learning. This new competitive setting offers a window of opportunities for developing countries that need to devise an appropriate industrial strategy to address these complexities and interdependencies.

In addition to providing insights about critical technological areas, TF can prove a valuable instrument to add coherence to S&T policy in developing countries but needs to be designed and implemented in conjunction with the country’s industrial strategy. The experiences we explored from South Korea, Brazil, Chile, and Argentina where this coherence has been sought successfully, provide preliminary support to our argument. The Argentine case also demonstrated that the macro-economic stability is a key factor facilitating TF policies and the government has shown concrete effort to overcome these bottlenecks through targeted sectroal policies.

Chapter 5

5. Discussion of main findings, policy recommendation and further research

5.1. Discussion of main findings and policy implications

The present thesis contributes to the evolutionary, labour market and innovation policy literatures by improving the understanding of the dynamics and policies driving structural change, along with its impact on cross-sectoral wage inequality.

The paramount importance of R&D and innovative activities in fostering economic growth is widely acknowledged (Furtado, 1961). Yet the distributive effect of innovation on cross-sectoral wage gaps still remains inadequately explored. Getting insight on why and how certain industries are leading to a deeper and faster structural change, with positive impact on workers' wages, is key to pursue a sustainable economic growth. The Ph.D. research filled this gap by adopting three different, but inherently linked perspectives from the three core papers: *Chapter 2* unravelled the *direction*, *dynamics* and *productivity dispersion* of structural change. Once the dynamics of structural change have been thoroughly understood, *Chapter 3* studied how structural change is linked to the distribution of average wages across industrial sectors, arguing that the specialization of a given industry is in explaining such a process. *Chapter 4*, by adopting an innovation policy perspective, examined how technology foresight policies can support developing countries to achieve structural change. *Chapters 2* and *3* focus empirically on the Argentine and Brazilian industrial development, whereas *Chapter 4* includes additional countries – Chile and South Korea -, through a policy-level case study, in order to enrich the conclusion to be drawn when analysing structural change from a different – more qualitative -angle.

The following paragraphs summarize the contributions provided by each core chapter. Section 5.2. provides the venues for future research.

Chapter 2 developed a novel approach to examine and compare the trajectories of structural change in Brazil and Argentina. The analytical strategy, assessing productivity growth dynamics, built upon and expanded traditional measures of productivity specialization, growth and heterogeneity

(Fagerberg, 2000, Holland and Porcile, 2005, McMillan and Rodrik, 2011) providing interesting results with respect to the industrial performance that we explicitly analysed with an historical perspective. In particular we investigated: the *direction* of structural change measured as the shift of industrial value added towards R&D intensive sectors; the *dynamic*s of structural change, calculated through a productivity decomposition analysis, in order to reveal the macro-sectors that most notably trigger – or fail to trigger – structural change; and the *productivity dispersion* of structural change measured by the variation of productivity levels within each of the macro-sector.

With exception of the ISI period – during which both Brazil and Argentina were featured by relatively higher dynamism of R&D industries' value added along with the highest employment growth – results strongly indicate that two distinct models in terms of *direction* and *dynamics* of structural change distinguish the two countries.

As far as *direction* is concerned, Argentina shows a relatively more pronounced specialization in the NR-based sectors. After the military coup in 1976, NR industries dominated the manufacturing industry in terms of value added generation – as well as employment absorption - at the expense of the R&D intensive sectors, that progressively lost ground. Brazil, despite being similarly characterized by a pronounced orientation towards NR industries, shows a gradual but persistent catch up of R&D based industries' value added which, at the end of the period, almost reached that of NR-based sectors. The Brazilian R&D value added race to the top is indicative of a virtuous industrial performance, which can eventually help reducing the low diversification of its economy. Both countries lost ground in the LI industries with some major downswings in footwear - especially in Brazil - clothing and furniture, due to the fierce competition from newly developed Asiatic countries. The competitive pressure caused by the trade liberalizing reforms of the 1990s, pushed overall productivity upward, though in Argentina it appears to be spurious (Furtado, 1961). Here, in fact, the rise in productivity was mainly driven by dramatic drop in employment, rather than a growing output. In contrast, in Brazil the drop of output was significantly smaller and it went along with an increase - rather than a decrease - in employment. Furthermore, the process of employment loss in the manufacturing industries began much earlier in Argentina, in the 1980s, than in Brazil, where it started in the 1990s.

The productivity decomposition shed some light on the *dynamics* driving productivity growth and structural change (represented by the between component of the productivity decomposition *formula*). The value added of our work with respect to the existing literature lies in the breaking down of the productivity decomposition at a macro-sectoral level, by focusing on productivity and output (as opposed to productivity and employment, as for the works of Fagerberg, 2000, Holland and Porcile, 2005, McMillan and Rodrik, 2011). The results indicate that the dynamics of structural change play a key role in determining the divergent performance of productivity growth which, again, sees Brazil in a relatively more favourable position than Argentina. While NR industries are the main triggers for structural change in Argentina, R&D industries – the most dynamic sectors according to the adopted classification - play this role in Brazil. In both countries NR -, contrary to LI - and R&D - intensive industries, are characterized by the highest degree of *productivity polarization*; this is symptomatic of economic backwardness resulting from the scant R&D and technological penetration. If Argentina continues to persist in such productivity growth/structural change trajectory - high NR value added associated to its high potential in triggering structural change and pronounced productivity polarization- this is likely to accrue the low diversification and dynamism of its production structure, whereby industrial policy has shown itself to be weaker and more discontinuous than in Brazil. In turn Brazil has demonstrated that despite a dominance of NR intensive industries, the R&D intensive sectors not only managed to catch up with the NR-based ones in terms of value added, but also in their capacity to trigger structural change. Furthermore, trade liberalization reforms in Brazil did not generate the dramatic loss in labour force that instead affected Argentina.[54] A clearer enforcement of R&D intensive industries' productivity and value added is advisable both in Argentina - to a greater extent given its relatively weaker position - and in Brazil to support structural change and sustain the diversification of the production structure. This would in turn reduce the vulnerability suffered by both countries bound to the volatility of the commodity prices, which cannot constitute the only value added of the economy, especially when adopting a long-term perspective. It is often the case that, in developing countries like Argentina and Brazil, trade-offs often privilege short-term gains (due to the conspicuous presence of highly demanded commodities) by foregoing long-term opportunities (Ascher, 2009). This is a dilemma: developing countries need to overcome such short-sightedness through foresight policies tailored to the skills and abilities of

[54] See Novick *et al*., (2007) where it is further specified that such employment loss was largely due to the twin forces of trade liberalization and a bad management of the exchange rate.

policy makers, cultural setting, the quality and the size of the human capital and technological availability (*ibid*) (see *Chapter 4*).

Chapter 3 provided novel evidence on the link between structural change and cross-sectoral wage inequality. While several empirical papers have extensively explored the relationship between structural change and the "within" sectors inequality, to the best of our knowledge there has been no attempt to examine the effect of structural change on the "between" sectors inequality, which is of vital importance when adopting a macro-economic perspective. A macro-economic understanding of how inequality actually occurs at a sectoral level and for a relatively long time frame (38 years) is key for policy makers. In this way efforts can be geared towards those sectors that are promoting innovation and diversification of the economy and where the wage *premiums* is linked to productivity and structural change forces, rather than towards those sectors featured by the mere speculation of – volatile - commodities prices. As a complement to these studies, this chapter examined whether, and if so to what extent, workers can benefit from wage *premiums* by way of productivity, gross margin and trade dynamics – identified as channels of structural change - and whether these effects are significantly different depending on the macro-sector the worker is employed. The insights gained from the previous chapter were crucial in order to provide a solid platform to contextualize the actual impact of structural change on industrial wages. Cross-sectoral inequality, measured as the logarithmic ratio between the sectoral average wage per worker and its median by macro-sector adapted from Mahler *et al*. (1999), appears to be more volatile and at times overlapping in Argentina than in Brazil – especially in the case of R&D and LI industries. Specifically, in Brazil the level of sectoral wage inequality is the lowest in R&D industries. Most likely, the more equal capital and technological penetration in the R&D group, the more directly they are reflected in a more uniform distribution of sectoral wages (since, in principle, wages should follow productivity). NR industries in both countries display the second most unequal level of inequality - though in Argentina at times it overlaps with the inequality level of R&D industries. The highly differentiated profitability of these industries (Holland and Porcile, 2005) is reflected by the presence of high-paid/high-productivity sectors, like oil, with low-paid/low-productivity sectors, like wood products. LI industries in both countries display among the highest level of wage gap, evidencing a sizeable deviation of the mean wage in LI intensive sectors from the median of that macro-sector.

Turning to the actual link between structural change and wages, our results strongly suggest that for the overall sample - and Brazil separately considered

- when both trade openness and import penetration loom large in R&D intensive sectors, domestic production benefits from it and so do wage *premiums*. In fact, these sectors and the relatively more skilled workers they employ, tend to respond more flexibly to crises or demand shocks. Hence, R&D industries seem to act as a springboard between structural change and higher wage gaps, both through trade openness, by providing more room for higher production and hence higher wage *premiums*, and through import penetration, presumably because imports within these industries are likely to complement, and hence to reinforce, the local manufacture. In contrast, the effect of trade openness and import penetration in NR intensive industries seems to push wage gaps downwards. These industries tend to be highly centralized, capital intensive and dismissive of domestic knowledge generation (Cimoli and Katz, 2003). These factors certainly constrain the positive transmission mechanism between structural change, *via* trade dynamics, and high wage *premiums*. Such result corroborates our assumption that import penetration within this macro-sector is likely to replace – and not to complement, as it occurred in the R&D group - the domestic production, with a detrimental impact on wages and, *ceteris paribus*, on wage gaps. Similarly, openness negatively impacted the performance of sectors which, by adopting a defensive and opportunistic behaviour (Katz and Cimoli, 2003), jeopardized wages and wage gaps. Consistent with our hypothesis, for both countries jointly and separately considered a rise in productivity is associated with higher wage gaps, though the effect is more evident in Brazil. Conversely, gross margin, representing the gross profit of enterprises, is negatively linked to sectoral wage gaps. This result might be explained by the fact that the higher is the share of revenues going to profits (or gross margin), the lower is the share of revenues benefiting wages and, all else being equal, wage gaps. The fact that the separate model for Argentina did not provide significant results - with exception to the lagged value of the dependent variable itself - suggests that in Argentina, unlike Brazil, structural-change related factors did not significantly contribute to the generation of higher wage *premiums*.

The following policy implications emerge from this analysis. In *Chapter 2* we found that in Brazil and Argentina there are two different engines for structural change: R&D intensive industries and NR intensive industries respectively. Yet, in the current chapter, we discovered that only the former industries act as a vehicle for higher sectoral wage *premiums.* This would imply workers would on average benefit from higher wages when structural change acts in the most R&D and technological intensive sectors. Besides, since average wages in R&D macro-sector are more equally distributed across sectors (probably due to a more equal capital and technological penetration) an enforcement of these industries would lead to a less polarized cross-sectoral wage distribution. High cross-sectoral wage inequality is in turn a distinctive feature of NR intensive industries. Hence, if increased trade openness and import penetration in R&D intensive industries increase wage gaps, and these wages among the R&D macro-sector are more equally distributed, efforts to shift resources from traditional NR industries towards more technological intensive ones are of foremost importance, or else to include a higher technological content within NR intensive industries. These efforts might include, for example, encouraging the development of competences on differential technological skills, assets and organizational routines that ultimately platform for a sector's ability to be competitive over time (Nelson and Winter, 1982).

Finally it is important to point to the limitations of this analysis. First, given the lack of data at a worker level within each industry, it is not possible to test the effect of structural change on different occupational categories, and hence to understand the drivers of the "within" sector wage inequality. More disaggregated data would enhance the detail of analysis and enable testing SBTC and trade related causes of wage inequality. Data at the employment level are available for each country, but they usually come at the expense of spanning over a shorter time frame which is not congenial to examine the impact of structural change thoroughly. More disaggregated data would also come at the expense of a reduced possibility to undertake cross-country comparison, as each country has its own definition and conformation of "occupational category". A second shortcoming of this study lies in the macro-sectoral classification (PADI, 2001) as the separation between NR, LI and R&D can oversimplify the complex nature of industrial sectors. The structure of industries changes along with technological revolutions. NR industries do not necessarily exclude R&D content in their specification, as in some sectors NR and R&D coexist. For instance, if we consider the role of technology in the Argentinian soybean or the Brazilian biofuels industries, it is evident that NR resources are far from being a coarse from which it was crucial to keep back. They to some extent prove to be highly knowledge-intensive sectors. Unfortunately the aggregation of our classification does not account for these sector's specificities. Furthermore, to provide a solution to this problem it would be necessary to build a dynamic classification changing over time and across countries, which to our knowledge is not available. We believe that the costs of simplifying the reality by forcing sectors into specific classifications is, anyway, compensated by the benefit of analysing the industrial sector for such a long period (38 years).

Chapter 4 by embracing a policy perspective, asked how Technology Foresight (TF) exercises can help developing countries to pursue growth and structural change. We addressed four case studies including South Korea, Brazil, Chile, and Argentina where the link between TF exercises and industrial strategies appears to be especially important at the policy perspective. In fact, TF exercises by promoting the systematic approach in looking into the longer-term future of S&T and innovation concretely help making better-informed policy decisions to where the future and hence the structural change will lead (Irvine and Martin, 1984). In *Chapter 4* we made an explicit effort in unravelling whether, and to what extent, technology foresight strategies need to be mutually consistent, coherently designed and implemented with the industrial ones in light of their role to foster structural change.

First, we examined the case of South Korea, a now-developed country, which served as a best-practice reference. Here, clever industrial policies joint with a foresighted national vision clearly contributed to achieve a well-defined and unprecedentedly fast economic growth. Some distinctive features appear to have contributed to its development. The first was the single-minded objective to pursue economic growth, which has been the foremost goal for all South Korean governments. The second concerns the complementarity between trade and industrial policies that helped the structural transformation of the economy. The promotion import/exports and FDI were leveraged according to the necessity to access new technologies and/or acquisition of new capabilities. The third was the governmental capability to engage the private sector in the development process within both TF exercises and development plans, by stimulating its ownership and responsibility. The explicit conceptual and practical link between South Korean TF exercises and industrial development makes it a suitable example to follow for other emerging economies.

Second, we investigated the case of Brazil, where the integration between industrial strategies and TF exercises demonstrated the country's ability to fully understand the new dynamics of GVCs. Of particular note is the governmental effort to leverage its large and growing internal market to build domestic capabilities in the consumer electronics sector. Thanks to the adoption of a foresighted approach, a centrepiece of Brazil's governmental strategy to increase local production of consumer electronics has been to attract global contract manufacturers, known in the industry as electronic manufacturing services (EMS) providers. As electronic lead firms such as Apple and Hewlett Packard continue to outsource manufacturing, contract manufacturers have become increasingly important players in the component purchasing, assembly, test, and after-sale service functions of electronics

GVCs. Thanks to Brazil's industrial policies and direct pressure on the company from policy-makers, Foxconn has begun to assemble iPhones, iPads and most recently iPad minis for Apple in Brazil. While Foxconn currently imports 90-95% of its components, the company is likely to begin to manufacture components, including displays, in Brazil. The focus of Brazil's industrial policy to attract investments from contract manufacturers, as well as GVC lead firms, signals a sophisticated understanding of the dynamics of the electronics GVCs. Contract manufacturers provide a leading edge, flexible, and scalable platform for local production and R&D. Furthermore, the Brazilian case suggests that learning within GVCs is possible if supported by appropriate policies.

Third, we explored the institutional development in Chile that, despite significant investments and a favourable macro-economic environment, has not yet succeeded in becoming an innovation-based diversified economy (OECD, 2013). However, here the government set up an institutional framework embodied by the National Council for Innovation and Competitiveness (CNIC) that would appear to favour the coherence and close connection between industrial strategy and TF with a long-term perspective. CNIC has the potential to act as a key foresight actor within the Chilean NIS, since it already initiated a process to establish an innovation culture in the country with a stronger interaction between the public and private sectors. Consequently, this institutional set up promises to help the country address the typical dynamic inconsistency and distance between TF and an appropriate industrial strategy.

Finally, we addressed the role of TF in Argentina, which contrary to South Korea, serves as counterfactual example indicating how an unstable/volatile macro-economic environment can actually inhibit the generation of a fertile environment where TF can flourish. Despite this unsettling environment, the Argentinian government, sustained by the financial and technical support of big banks such as the IADB and World Bank, embarked on a series of targeted sectoral measures through the establishment of key sectoral funds, to tackle coordination failures derived from the incorporation of technological change within each sector. The final aim was to generate greater technological impacts in a shorter time frame targeting businesses' competitiveness, especially SMEs. The sectoral funds launched around middle of 2000s seem to have performed quite well according to evaluation reports (IADB, 2014). Another significant area where TF policies became integral part of broader industrial strategies, is represented by the successful performance of some key sectors, such as the bioenergy one, that sees Argentina as a world-leader in biodiesel production. The active governmental engagement has demonstrated to be essential in providing a suitable regulatory framework to support its production. Overall *Chapter 4* showed that TF can prove a valuable instrument to add coherence to S&T policy in developing countries as long as its design and implementation are mutually consistent with the industrial strategies. The experiences we explored from Brazil, Chile, South Korea and Argentina where this coherence has been sought successfully, provide preliminary support to our argument.

5.2. Directions for further research

Based on the experience and knowledge gained through the course of the present thesis the following directions for further research are suggested.

Further research at the international level on the effect of structural change on wage inequality should focus and complement a micro with a micro-level perspective on earnings disparities. For instance as a next step could involve the combination and matching two Brazilian databases on the basis of sector classification: the PADI focusing on industrial average sectoral wages, and the Annual Social Information Report (RAIS) focusing employment, educational level and wages for the period 1996-2013 for which data are readily available by professional category. The combination of this within-sector variation in inequality, together with the time variation on structural change and between-sector inequality, would allow ascertain whether those sectors where structural change occurred, also experienced a decrease in within-sector wage inequality. At the same time, and as a complement of our measure of cross-sectoral wage inequality, this would shed light as to which are the micro-causes of a more homogeneous distribution of cross-sectoral wages. Are wages in R&D industries more equally distributed among these sectors due to a homogenous skill/experience distribution? This would help grasping the within-sector dynamics that are ultimately complement the defining a given trend in inequality at a sectoral level.

Finally thanks to *Chapter 4* we have understood that the long-term, coherent design of TF policies with industrial strategies framed in the GVCs for developing countries is crucial. An increasing share of global trade is now focused on capabilities and not products, which brings important implications from a TF/industrial policy perspective. By expanding the number of case studies to more countries, the argumentation could gain further support for other developing countries wanting to promote a more strategic, balanced and inclusive development trajectory.

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Erklärung, *Declaration*

Hiermit erkläre ich, *I state that*,

1. dass mir die geltende Promotionsordnung bekannt ist; *I'm familiar with the current Course of Examination for Doctoral Applicants*;

2. dass ich die Dissertation selbst angefertigt, keine Textabschnitte eines Dritten oder eigener Prüfungsarbeiten ohne Kennzeichnung übernommen und alle von mir benutzten Hilfsmittel, persönlichen Mitteilungen und Quellen in meiner Arbeit angegeben habe; *I have composed and written the dissertation by myself, that no passages of text have been taken from third parties or own exam papers without having been identified as such and that all tools, personal notifications, and sources used have been indicated in the dissertation*;

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October 2010- -October 2011	**MSc in Science and Technology for Sustainability, University of Sussex, SCIENCE AND TECHNOLOGY POLICY RESEARCH UNIT (SPRU)** Final grade: 72.35%. Supervisor: Professors Matias Ramirez and Nick von Tunzelmann.
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Work experience	
October 2011-July 2012	**Researcher, SCIENCE POLICY RESEARCH UNIT (SPRU),** UNITED KINGDOM Researcher in two projects: 1) **Brighton Fuse project**. Analysis of the creative cluster located Brighton & Hove with particular focus on enterprises performance and growth. Supervisor: Prof. Paul Nightingale; and 2) **Interdisciplinary Science**. Writing of a paper concerning the role of journal rankings in assessing monodisciplinary versus interdisciplinary research. Supervisor: Dr. Ismael Rafols.
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Publications	Pietrobelli, C. and Puppato, F. (2015) Technology foresight and industrial strategies in developing countries, Keynote paper for the workshop “Choosing Emerging Technologies for Development”, UNU-Merit Working paper 2015-16, *Technology Forecasting and Social Change*, forthcoming. von Tunzelmann, N. and Puppato, F. (2012) Dynamics of Network Alignment to be published in the special issue of the *Journal of Knowledge Economy*, forthcoming.
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Jena, 24th January 2016

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